SEQUENCE STRATIGRAPHY AND DETRITAL ZIRCON GEOCHRONOLOGY OF THE SWAN PEAK QUARTZITE, SOUTHEASTERN IDAHO

A Thesis

by

TRACY DAVID WULF

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2011

Major Subject: Geology

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Approved by:

Chair of Committee,	Michael Pope
Committee Members,	Brent Miller
	Deborah Thomas
Head of Department,	John Giardino

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ABSTRACT

Sequence Stratigraphy and Detrital Zircon Geochronology of the Swan Peak Quartzite, Southeastern Idaho. (December 2011)

Tracy David Wulf, B.S., Brigham Young University

Chair of Advisory Committee: Dr. Michael Pope

The supermature Middle-Late Ordovician Swan Peak quartz arenite was deposited on the western Laurentia passive margin and is very fine to fine grained, well-rounded, well-sorted, and silica-cemented. Laurentia was positioned over the equator during the Middle-Late Ordovician, suggesting that basement rock along the Transcontinental Arch was intensely eroded in a humid climate to produce this and other coeval quartz arenites. To determine provenance for the Swan Peak Quartzite, zircon grains were analyzed using LA-ICP-MS and the results were constrained within a sequence stratigraphic framework.

Depositional environments of the Swan Peak Quartzite record an offshore-to-onshore transition with five facies (A-E). Facies A only occurs at the base of the Bear Lake section and may record an incised valley or localized embayment. It is the deepest water facies in the succession containing shale and quartz arenite interbeds. Facies B through E are interpreted as lower, middle, upper shoreface/foreshore depositional environments, respectively, based on primary sedimentary structures and bioturbation.

Detrital zircon age spectra of the Swan Peak Quartzite have four distinct populations: the two main populations are at 1.8 – 2.0 Ga (Paleoproterozoic) and between 2.5 – 3.0 Ga (Archean), with a smaller, but persistent, population at 2.0 – 2.1 Ga, and a very minor 0.8 – 1.2 Ga (Mesoproterozoic) population occurring mainly in the tops of the measured sections. The base of each section has a larger Archean peak whereas the top of each section is predominantly Paleoproterozoic grains. Zircon data have overlap and similarity values ranging between 0.531 – 0.771 and 0.506 – 0.881, respectively, which indicates zircon age spectra of the Swan Peak Quartzite is similar to other Cordilleran Ordovician quartzites and that recycling of heterogeneous underlying sedimentary rocks was minimal.

The Wyoming Craton (2.5 – 2.8 Ga) and the Trans-Hudson Orogen (1.8 – 2.0 Ga) provinces near the paleoequator likely provided the majority of zircons in the Swan Peak Quartzite. The source for the 2.0 – 2.1 Ga grains is currently unknown and the 0.8 – 1.2 Ga grains are interpreted to reflect Mesoproterozoic Laurentian tectonism. Sediment input varied in response to sea level fluctuations. Longshore transport was likely an important process in redistributing grains along the coastline during later deposition of the Swan Peak Quartzite.

DEDICATION

To my wife and parents who encouraged me to push to the finish.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. Michael Pope, and my committee members, Dr. Brent Miller, and Dr. Debbie Thomas, for their guidance and support throughout the course of this research and countless revisions.

Thanks also go to my friends and colleagues and the department faculty and staff for making my time at Texas A&M University a great experience. I also want to extend my gratitude to Dr. Jeff Vervoort and Charles Knaack, who provided lab analysis technical support at Washington State University.

Finally, thanks to my mother and father for their encouragement and to my wife for her patience and love.

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INTRODUCTION

The Middle-Late Ordovician Swan Peak Quartzite of southern Idaho (Fig. 1) is a quartz arenite deposited along the Lower Paleozoic Laurentian passive margin. This supermature siliciclastic unit and its lateral equivalents (e.g. Eureka Quartzite, Mt. Wilson Quartzite, Kinnikinic Quartzite, etc.) occur within a kilometers-thick Cambrian to Devonian carbonate-dominated passive margin succession. Typically, these quartz arenites range from 50-150 m thick along the western Cordilleran margin with local accumulations up to 500 m. Depositional environments range from non-marine to nearshore and shallow marine shelf, interfingering with shale and carbonate in deeper water environments (Webb, 1958; Ketner, 1968). Recent biostratigraphic data (Sweet, 2000) indicates that some of these quartzite units are Cincinnatian (451 – 443.7 Ma; Gradstein et al., 2004) deposited during an extensive continental flooding of the Paleozoic, instead of during a prolonged Middle Ordovician sea level lowstand (Webb, 1958). Previous work suggests that the source area for these sediments was the Peace River Arch, in northwestern Canada and that longshore currents transported these sediments 100’s to 1000’s of kilometers along the Ordovician shoreline (Ketner, 1968; Gehrels and Dickinson, 1995; Gehrels et al., 1995).

Deposition of the Swan Peak Quartzite and its lateral equivalents on a carbonate-dominated passive margin indicate a dramatic shift in either tectonic processes and/or

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paleoclimate. However, the lack of a detailed regional stratigraphic framework for these units has hindered understanding of their depositional history and provenance (Webb, 1958; Ketner 1968; Gehrels and Dickinson 1995, Gehrels et al., 1995). Here we present the sequence stratigraphy and detrital zircon geochronology of the Swan Peak Quartzite, evaluate its provenance, and determine if the provenance varies temporally and spatially as a result of relative sea level fluctuations.

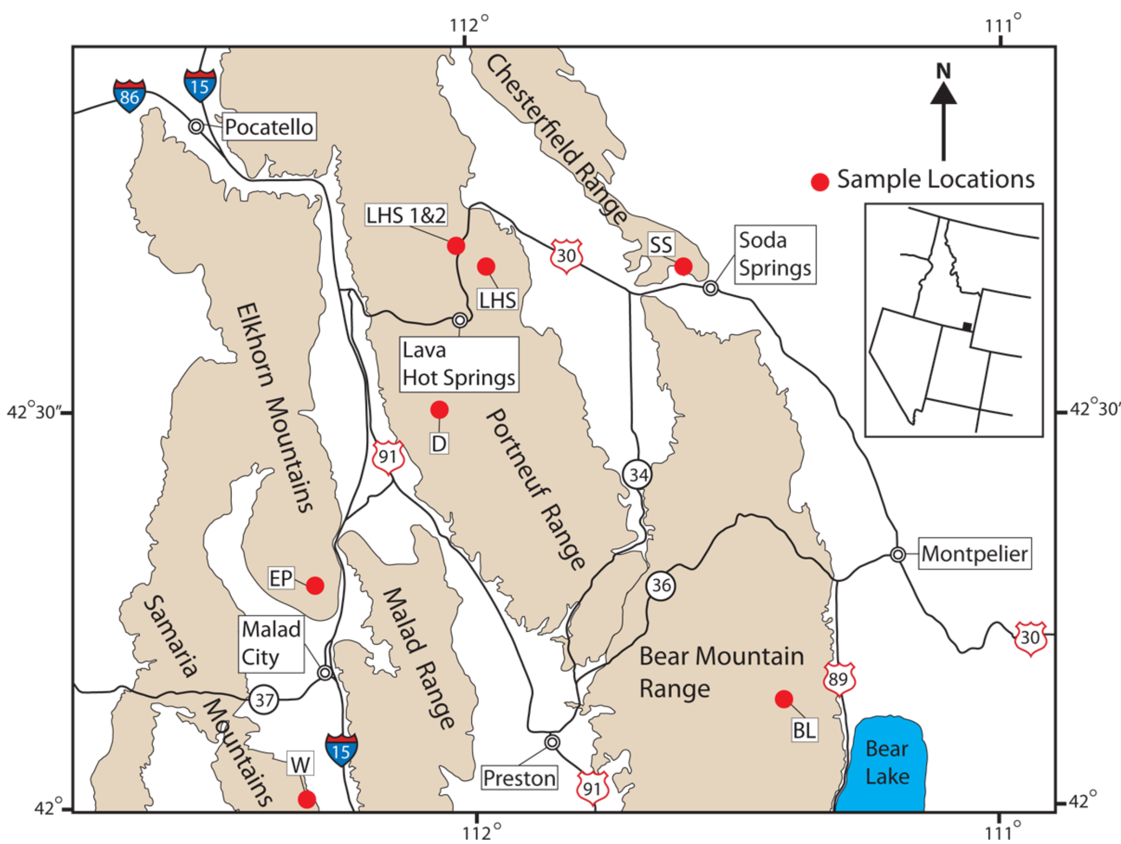


FIG. 1.—Index map of southern Idaho showing sample locations of the Middle-Late Ordovician Swan Peak Quartzite. BL – Bear lake, SS – Soda Springs, LHS – Lava Hot Springs, LHS 1&2 – Lava Hot Springs Road Cuts 1&2, D – Downey, EP – Elkhorn Peak, W – Woodruff.

GEOLOGIC SETTING AND STRATIGRAPHY

The western margin of Laurentia accumulated thick successions of mostly carbonate rocks from the Early Cambrian to the Early Devonian, with deposition taking place at or near the equator, on either side of the Transcontinental Arch (Witzke, 1980). The Ordovician Swan Peak Quartzite with its lateral equivalents (e.g. Eureka Quartzite, Mt. Wilson Formation, Kinnikinic Quartzite, etc.) consists of very fine- to medium-grained, moderately to well-sorted, silica-cemented quartz arenite (Webb, 1958; Ketner, 1968; Dott et al., 1986; Druschke et al., 2009). These units represent the only significant mature quartz arenite deposition on the otherwise carbonate-dominated Lower Paleozoic passive margin.

These quartzite units were traditionally considered massive and relatively featureless (Dapples, 1955; Webb, 1958; Ketner, 1968). However, these rocks contain a wide range of primary sedimentary structures including herringbone cross-bedding, hummocky cross stratification, horizontal planar- and low-angle cross-stratification, stromatolites, and abundant trace fossils (e.g. James and Oaks, 1977; Oaks and James, 1980; Biek, 1999; Druschke et al., 2009). These sedimentary structures are consistent with deposition across an offshore-to-onshore transition as part of the shallow shelf and shoreface high-energy environments (Dott et al., 1986; Hall, 1989; Zimmerman and Cooper, 1999; Druschke et al., 2009). Shale and carbonate interbeds increase seaward in low energy deeper subtidal settings (Webb, 1958).

The basal contact of these quartz arenites commonly is sharp and disconformably overlies Middle to Late Ordovician carbonate units. However, locally this unit unconformably overlies Precambrian metasediments or Cambrian plutons in east-central Idaho (Sloss, 1954; James and Oaks, 1977, Link and Janecke, 1999; Link, 2007). In some locations, the basal contact is gradational (Oaks and James, 1980) where the underlying units are interbedded carbonate and siliciclastic rocks. The upper contact ranges from disconformable to unconformable and commonly is a sharp surface marked by a quartz arenite overlain by Upper Ordovician sandy dolostone that within a few meters becomes open-marine limestone or dolostone with very little or no siliciclastic content (Leatham, 1985; Measures, 1992; Harris et al., 1995). The Upper Ordovician dolomite records the most extensive cratonic flooding of the Paleozoic (Beus, 1968; James and Oaks, 1977; Oaks and James, 1980, Witzke, 1980; McLaughlin et al., 2004).

Paleogeography

The Transcontinental Arch was situated near the paleoequator during the Middle-Late Ordovician (Witzke, 1990; Van der Voo, 1993; Scotese et al., 1999; Scotese, 2002). Its paleoequatorial position suggests a humid climate able to produce abundant siliciclastic detritus (Chandler, 1988). The St. Peter Sandstone, an Ordovician quartz arenite coeval to the Swan peak Quartzite, is a first-cycle quartz arenite formed in a humid equatorial setting (Dott et al., 1986; Dott, 2003). The environment needed to produce first-cycle quartz arenite requires intense chemical weathering and extended time for weathering to occur within a humid climate (Johnsson et al., 1988). The position of Laurentia during the Middle-Late Ordovician is such that the

Transcontinental Arch experienced conditions favorable to produce these first-cycle quartz arenites.

First-cycle sediments are characterized by the presence of less resistant minerals and rock fragments. However, first-cycle detritus may change as a result of different weathering environments. Immature first-cycle quartz arenites tend to form in arid climates while mature first-cycle quartz arenites are produced in humid climates (Dutta and Suttner, 1981, van de Kamp, 2010). The Swan Peak Quartzite lacks any feldspar minerals or any other less resistant minerals or rock fragments as a result of prolonged and intense chemical weathering (Johnsson et al., 1988), and is a supermature first-cycle quartz arenite indicative of a humid, tropical climate (Dutta and Suttner, 1981; van de Kamp, 2010).

Geochronology

Conodont biostratigraphy constrains the depositional age of the Cordilleran Quartzites. Early studies (Fig. 2) suggested they were deposited during the Whiterockian (462 – 471.8 Ma) to Mohawkian (451 – 462 Ma; Ross, 1959; Ross, 1961; Churkin, 1962; Hobbs et al., 1968; Ruppel et al., 1975; Gradstein et al., 2004; Leslie and Lehnert, 2005). Additional conodont studies of the Eureka Quartzite and the overlying sandy dolostones indicate that part of the Eureka Quartzite (Fig. 2) and its equivalents (e.g. Swan Peak Quartzite, Kinnikinic Quartzite, Mt. Wilson Formation, etc.) were deposited during the Cincinnatian (443.7 – 451 Ma; Sweet, 2000; Gradstein et al., 2004).

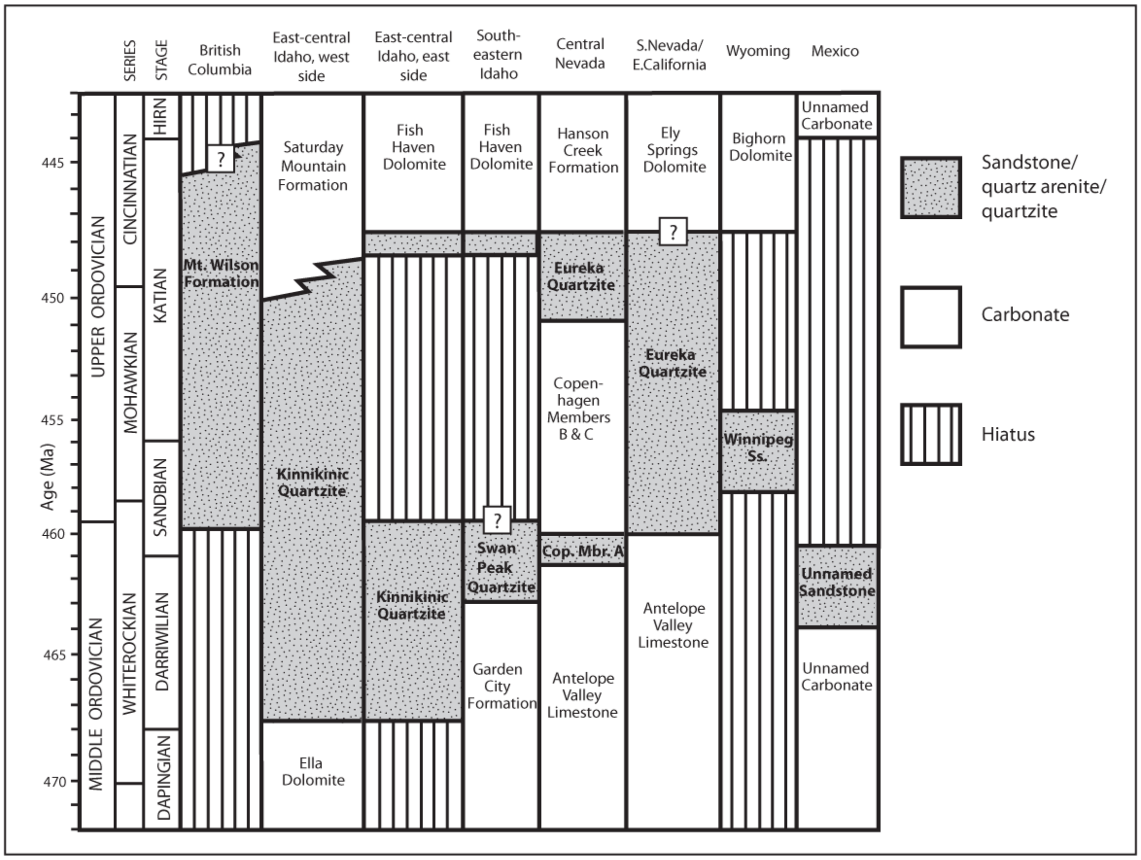


FIG. 2.—Conodont biostratigraphy constrains the Ordovician quartz arenites along the Laurentian passive margin between the Darriwilian and Katian stages. Duration of units are modified from Churkin (1962), Hobbs et al. (1968), Norford (1969), James and Oaks (1977), Harris et al. (1979), Poole et al. (1995), Suhm (1997), Biek (1999), and Saltzman and Young (2005).

PREVIOUS WORK

Initial provenance studies for the Middle-Late Ordovician quartzite units along the western margin of Laurentia were based on Thermal Ionization Mass Spectrometry (TIMS) analysis of four detrital zircon samples and a total of 158 grains (Gehrels et al., 1995; Gehrels, 2000). These zircon grain populations have mostly a bimodal age range from 1.8 – 2.0 Ga and 2.5 – 2.8 Ga, with a smaller, persistent population of 2.1 Ga grains. These samples also contain a rare population of 0.8 – 1.2 Ga grains. Subsequent laser-ablation-inductively-coupled-plasma mass spectrometry (LA-ICP-MS) of ≈ 400 detrital zircons from the same four samples (Fig. 3) verified the original TIMS age distribution (Gehrels pers. com., 2008). These data were interpreted to indicate the dominant source for these sediments was the Peace River Arch in northern British Columbia (Gehrels and Dickinson, 1995; Gehrels et al., 1995; and Gehrels, 2000), suggesting sediment was transported over 2000 km by southerly longshore currents along the passive margin. This depositional model is supported by a north to south decrease in grain size and increase in sediment sorting and rounding (Ketner, 1968). This long distance transport model proposes that little or no sediment was locally derived from potentially exposed basement source areas east of the passive margin, or from recycling of underlying Precambrian to Lower Paleozoic siliciclastic rocks, even though these potential sources were positioned near the equator (Scotese et al., 1999; Scotese, 2002; Blakey, 2011) and likely subjected to intense equatorial weathering.

The Swan Peak Quartzite in southeastern Idaho has primary sedimentary

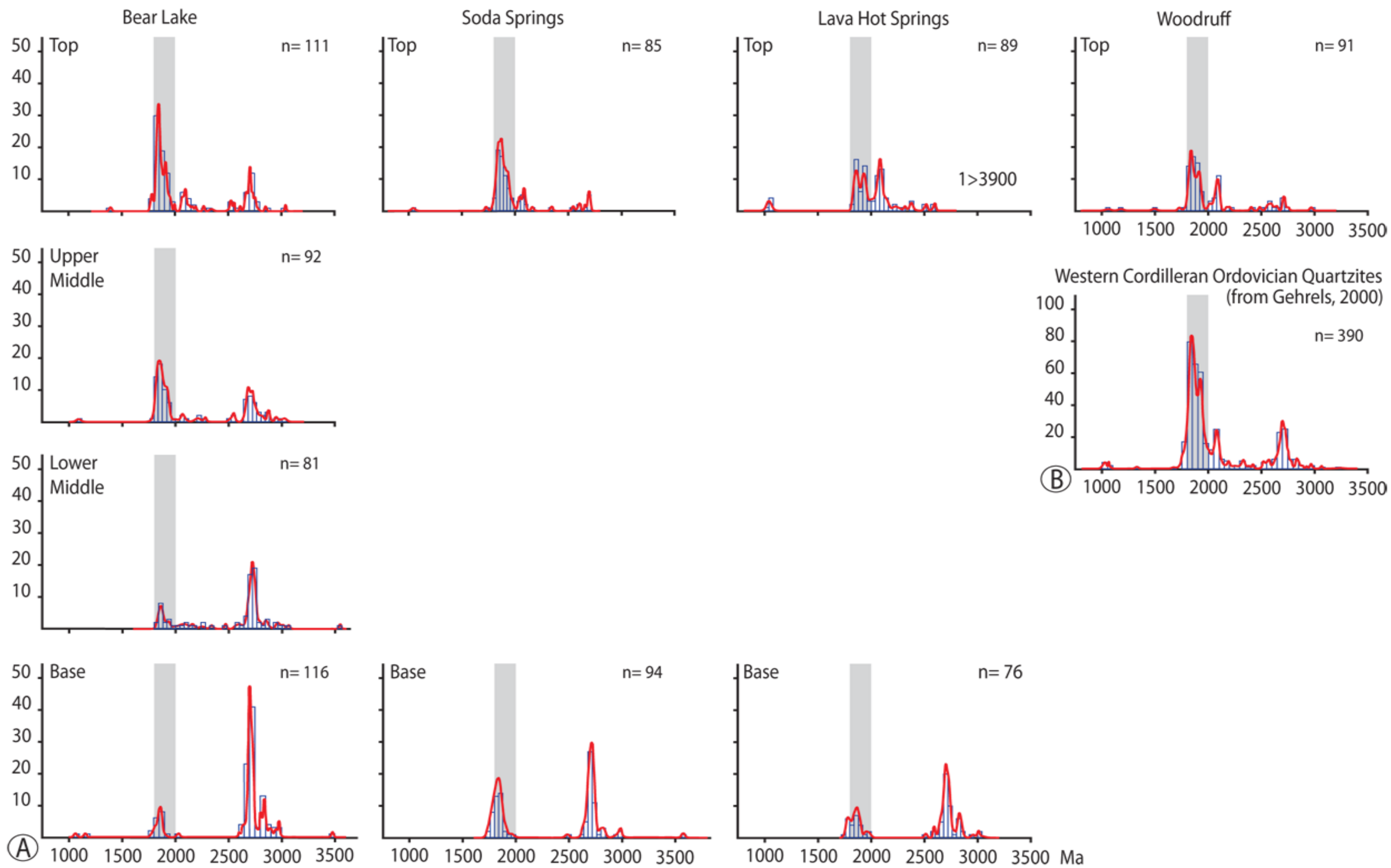


FIG. 3.—A. Detrital zircon age spectra for the Swan Peak Quartzite. Gray bars highlight the 1.8 – 2.0 Ga grains, horizontal axes are ages in Ma, vertical axes are the number of grains, and irregular lines are the relative probability. B. For reference, detrital zircon age spectra from four samples in Middle-Late Ordovician quartzites along the western Cordilleran margin (Gehrels pers. com., 2008) as compared to zircon age spectra for the Swan Peak Quartzite. The Swan Peak analyses are similar to the Ordovician quartzites along the entire Cordilleran passive margin.

structures and stratigraphic surfaces that provide a framework for siliciclastic sequence stratigraphic analysis of this unit. Proximal basement sources and the Transcontinental Arch may have been the primary contributor of sediment for this unit. Detrital zircon analysis from the Middle-Late Ordovician Harding Sandstone in Wyoming (Pope, 2008) and the Kinnikinic Quartzite in south-central Idaho (Baar, 2008) indicates that the sediment sources for these units were the Wyoming Craton and the Trans-Hudson Orogen.

METHODS

Fieldwork included measuring eight sections using a 1.6 m Jacob's staff. Detailed description of each section was bed-by-bed which varied in thickness from 30 cm to greater than 1.5 m. Samples were taken from each measured section at stratigraphically important horizons based on grain size changes or changes in the amount of bioturbation. Samples (~5 kg) were collected from fresh surfaces with a rock hammer that was cleaned between samples with a wire brush. Five samples were analyzed from the tops and bottoms of three measured sections and two samples were analyzed from the middle portion of the Bear Lake section as data were already available from the top and bottom of this section (Pope, 2008).

Zircon Separation

Seven detrital zircon samples were processed in the mineral separation lab at Texas A&M University. The mechanical separation processes included hammering the samples into smaller, cm-scale pieces followed by standard crushing with the jawcrusher and subsequent disc milling. The detrital zircon grains were concentrated using a Wilfley table at a peak angle of 30˚. Neodymium-boron hand magnets were used to remove metallic fragments and/or grains from the samples, which was followed by methylene iodide (MEI) heavy liquid separation. After the heavy liquid separation, remnant lithic fragments or non-zircon grains were further removed by hand-picking using a microscope. The zircon grains and standards (FC-1 and Peixe) were mounted in a 1″ diameter epoxy resin puck. The pucks were polished using 6 μm, 1 μm, and 0.25

μm diamond polishing disks, and afterwards they were carbon coated. The pucks were scanned and imaged using a Cameca SX50 electron microprobe generating back-scattered electron (BSE) and cathodoluminescence (CL) images of each of the seven samples and standards. The images aided in determining the best location to analyze each grain and which grains to avoid as a result of internal zoning.

Data Analysis

Detrital zircon analysis has two main strategies, qualitative analysis and quantitative analysis (Fedo et al., 2003). In the qualitative approach, ages representing source components within individual zircon populations are sought. This approach was used to establish a reference point for the western Laurentian region that indicates all possible provenances contributing to zircon populations in the samples (Gehrels et al., 1995; Gehrels, 2000; Gehrels pers. com., 2008). The quantitative approach, as used in this study, seeks to be as representative of the total zircon population as possible (Fedo et al., 2003), and is a powerful technique enabling comparisons between the proportions of age components for each sample. However, data biasing becomes an issue and minimizing sample bias may enhance the randomness of grain selection. To avoid biasing, the grains in this analysis were scooped en-mass from a petri-dish and mounted in epoxy resin; and the only exclusion of grains was for those containing obvious inclusions or metamict zones. It is noted, though, that excluding grains with inclusions or internal zones is a bias and may lead to a missed zircon population.

At least 60 grains in a "worst-case" scenario need to be analyzed to reduce the probability to <5% of missing an age population in the sample (Dodson et al., 1988). In naturally occurring populations, statistically important age populations are less likely to be missed by analyzing at least 117 grains (Vermeesch, 2004). Achieving this larger dataset makes TIMS prohibitively time-consuming for this project, so zircons in this study were analyzed by LA-ICP-MS at Washington State University (WSU). The laser width was 30 μm and operated at 75-80% power at 5 Hz. The work was performed using a ThermoFinnigan Element2 magnetic sector double-focusing ICP-MS along with a New Wave Research UP-213 laser system. Data analysis and collection followed standard methods at WSU (Chang et al., 2006). Time-dependent fractionation caused by the laser was corrected by normalizing the measured ratios in the samples and standards using the intercept method (Chang et al., 2006). Fractionation caused during laser ablation and instrument discrimination was corrected using external zircon samples (Chang et al., 2006). Each sample had 100 grains analyzed for a total sample set of 700 grains from seven samples. Only grains that were <10% discordant are reported, and the others were culled.

Data Presentation

Data were reduced using methods described in Chang et al. (2006), and the data were plotted using Isoplot 3.00 (Ludwig, 2003). The data are presented in two graphs: the binned histogram and the probability density diagram. The binned histogram has two critical limitations (Sircombe, 2000; Fedo et al., 2003; and Vermeesch, 2004). First, histograms are based only on age measurements; the associated errors in the age are discarded. Second, the size and location of the bins are arbitrary (Davis et al., 1994; Gehrels and Dickinson, 1995; Roback and Walker, 1995, and Scott and Gauthier, 1996).

Therefore, a histograms appearance needs to balance between too much detail with narrow bin widths (under-smoothing of data), and too little detail (over-smoothing of data) and wider bin widths (Sircombe, 2000). The bin width for this data set is 40 Ma.

The probability density diagram attempts to address the limitations of the binned histograms (Sircombe, 2000) by including the individual age errors in calculating the probability density distribution and eliminating the potential for altering the appearance of the diagram caused from varying the bin widths of the histograms. However, a limitation of probability density diagram is the loss of easily accessible frequency information (Sircombe, 2000). The area beneath the curve conveys frequency and proportion information, such that the height on probability density diagrams is not just related to the total number of analyses in a specific age range, but also to the precision of the data within a specific age range (Sircombe, 2000). Binned frequency histograms and probability density diagrams are here used together (Sircombe, 2000; Fedo et al., 2003; Vermeesch, 2004).

DATA

Measured Sections

Eight total sections were measured in the study area (Fig. 1); however, only the four sections with zircon age spectra data are presented here. The Bear Lake section is located in the southeastern portion of the study area about 15 mi (24 km) from the Idaho-Utah border. Total measured thickness is 136 m; however true thickness is unknown since the basal contact with the Garden Creek Limestone is covered. The top of this section has an 18 m thick cross-bedded interval capped by a sharp disconformable surface overlain by a few meters of sandy dolomite of the Late Ordovician Fish Haven Dolomite.

The Soda Springs section is 50 mi (80 km) north of the Bear Lake section and is 207 m thick. The basal contact with the Garden Creek Limestone is covered but limestone outcrops occur a few meters below the basal quartzite. This section is capped by a 25 m thick bioturbated interval containing remnant cross-bedding. The upper contact with the Fish Haven Dolomite is a sharp and well-defined surface.

The Lava Hot Springs measured section is 20 mi (32 km) east of the Soda Springs section. This section is 217 m thick; however, the upper contact of this section was not measured as it is poorly exposed. The upper part of this section has an extensive (56 m) planar laminated interval. The basal contact with the Garden Creek Limestone and the upper contact with the Fish Haven Dolomite were both covered.

The Woodruff section occurs about 57 mi (92 km) south of Lava Hot Springs,

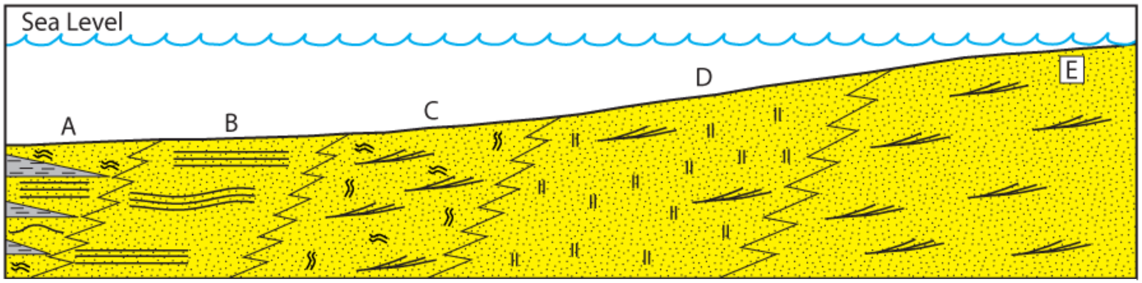


FIG. 4.—Schematic diagram showing offshore-to-onshore facies relationships of the Swan Peak Quartzite. Facies A – interbedded shale and planar laminated to hummocky crossbedded quartzite, distal shallow shelf; Facies B – planar to low-angle planar laminated, lower shoreface; Facies C – low-angle crossbedding, some vertical and horizontal burrows, middle-upper shoreface; Facies D – Burrows; *Skolithos* trace fossils "pipe rock," rare low-angle crossbeds, middle-upper shoreface; and Facies E – low-angle crossbedding, upper shoreface-foreshore.

near the southwestern limits of the study area. Only an incomplete upper section of the Swan Peak Quartzite is preserved as normal faults have disrupted the local stratigraphy. Most of this section is poorly exposed, but it is capped by a 4 m thick cross-bedded interval. The basal contact is covered, but the upper contact with the Fish Haven Dolomite is sharp and consists locally of 1.5 m of fault gouge.

Facies Description and Interpretation

Depositional environments in the Swan Peak Quartzite, in a west-east direction across the shelf, record a landward shift from distal shallow shelf to upper shoreface/foreshore deposits (Fig. 4). Facies A-E (Table 1) mark an offshore-to-onshore transition as part of a high-energy shelf to shoreface environment. Facies A is very fine grained, planar laminated to hummocky crossbedded quartz arenite interlayered with shale (Table 1). The quartz arenite beds contain abundant trilobite hash at the base of beds and occasional *Thalassinoides* burrows (Fig. 5A). The interbedded shale layers

TABLE 1.—*Unit descriptions and interpretations of depositional environments.*

Facies	Description	Interpretation
A	Very fine grained quartz arenite, well rounded and well sorted grains, thin bed sets, planar laminations and hummocky crossbedding, interbedded with thin shale beds, abundant trilobite hash and occasional trace fossil burrows	Storm layer deposits below storm wave base level, deposited on distal shallow shelf (Dott and Bourgeois, 1982; Midtgaard, 1996)
B	Very fine to fine grained quartz arenite, well rounded and well sorted grains, thin- to medium- bed sets, planar to low-angle planar laminations	High preservation of primary sedimentary structures within high energy lower shoreface (Greenwood and Mittler, 1985; Arnott, 1993)
C	Very fine to fine grained quartz arenite, well rounded and well sorted grains, medium- to thick- bed sets, low-angle crossbedding, occasional horizontal and vertical burrows	Some preservation of original sedimentary structures within high energy middle-upper shoreface (Reinson, 1984)
D	Very fine to fine grained quartz arenite, well rounded and well sorted grains, massive, thick bed sets, abundant *Skolithos* bioturbation froming "pipe rock," vertical burrows 30-40 cm in length	Sediment is completely reworked by organisms burrowing vertically to keep pace with high energy and increased sedimentation rates near middle-upper shoreface (Reinson, 1984; Desjardins et al,. 2010)
E	Very fine to fine grained quartz arenite, well rounded and well sorted grains, medium bed sets, low-angle crossbedding	High preservation of sedimentary structures of upper shoreface to beach complex (Reinson, 1984; Short, 1984)

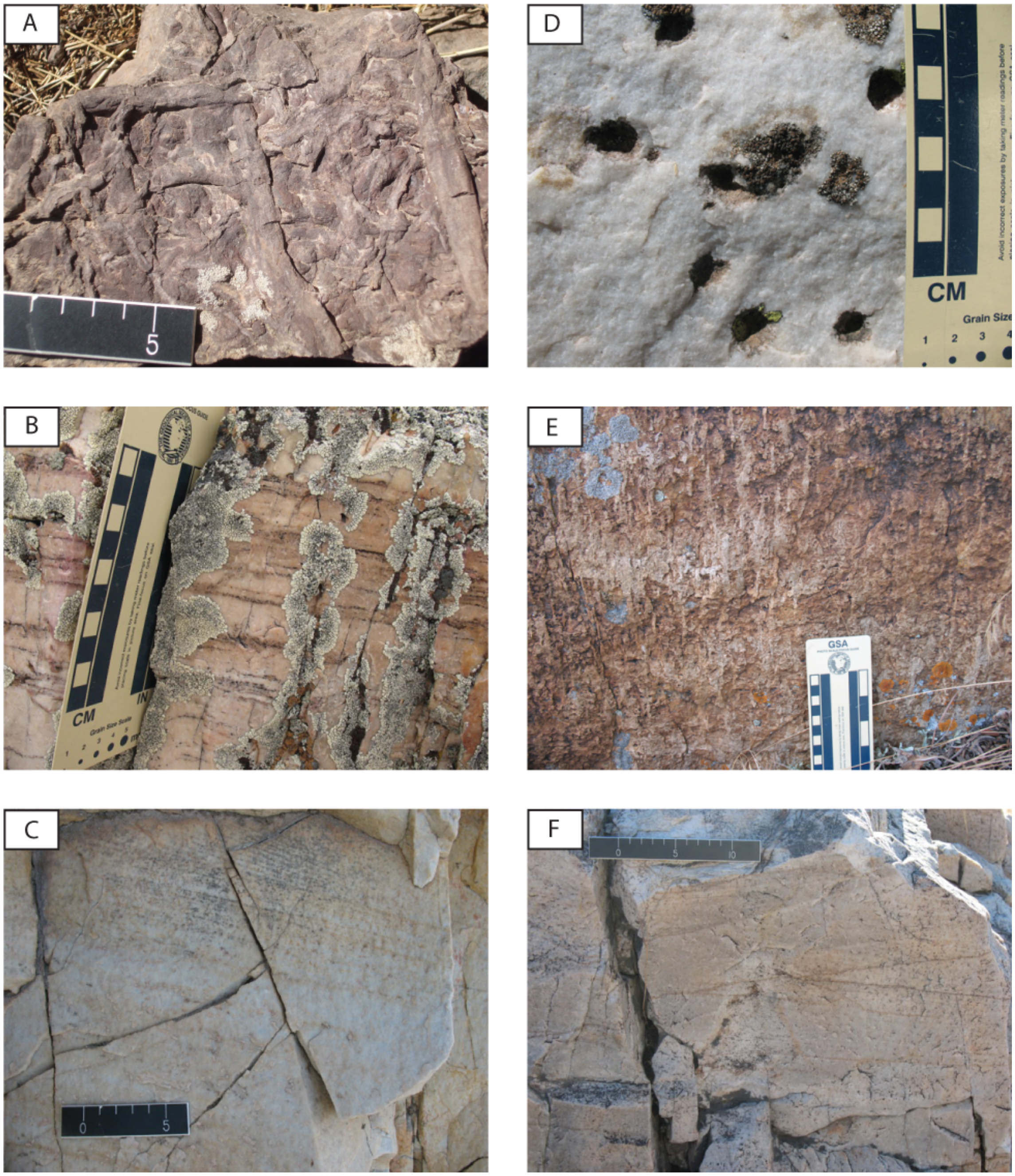


FIG. 5.—Primary sedimentary structures of the Swan Peak Quartzite. A) *Thalassinoides* bioturbation of Facies A; B) and C) planar- and low-angle planar laminations of Facies B; D) enhanced bioturbation from differential weathering of burrows generating pockmarks ranging from 1-3 cm in diameter from Facies C; E) *Skolithos* bioturbated “pipe rock” of Facies D; and F) low-angle crossbeds of Facies E.

were deposited below storm wave base in a low energy setting (Dott and Bourgeois, 1982; Midtgaard, 1996; Runkel et al, 2007). The thin-bedded quartz arenite is interpreted to be storm layer deposits on the distal shallow marine shelf (Dott and Bourgeois, 1982; Midtgaard, 1996; Runkel et al, 2007).

Facies A is unique to the basal portion of the Bear Lake section. This facies records a sea-level transgression with deposition of shale and quartz arenite interbeds, signifying relatively deeper water distal marine shelf facies grading upward into shallower marine facies (Dott and Bourgeois, 1982; Midtgaard, 1996; Runkel et al, 2007). This facies was likely deposited in an incised valley or a local embayment during the transgressive systems tract (TST) as sea level rose following the formation of the incised valley or embayment during the lowstand systems tract (Van Wagoner, 1995; Hiscott, 2001).

Facies B (Fig. 5B and 5C) is very fine-grained with planar to low-angle planar laminations. Bed thickness varies from thin to medium set beds (Table 1). Preservation of planar laminations indicates these sediments were deposited in a high energy environment (Arnott, 1993) as sediment was not extensively reworked by organisms. Preservation of primary sedimentary structures suggests a combination of increased sedimentation rates or a poor environment for organisms to subsist and rework the sediment (Arnott, 1993). The lack of bioturbation and good preservation of planar laminations suggests this facies is a lower shoreface deposit (Greenwood and Mittler, 1985; Arnott, 1993).

Facies C (Table 1) is very fine- to fine-grained, low-angle crossbedded quartz arenite with medium to thick bed sets (Fig. 5D). Occasional horizontal and vertical burrows occur, and locally these burrows completely rework the sediment. The burrows oftentimes are weathered substantially creating pockmarks 1-3 cm in diameter (Fig. 5E). Deposition of low-angle crossbeds requires a high energy flow regime with ample sediment supply (Reinson, 1984; Runkel et al, 2007). Moderate preservation of primary sedimentary structures of Facies C and the occurrence of occasional burrows is interpreted to be middle to upper shoreface environment (Reinson, 1984; Runkel et al, 2007).

Facies D is a very fine- to fine-grained, massive quartz arenite with rare remnant low-angle crossbeds (Table 1). Consistent thick set beds are common with abundant *Skolithos* burrows (Fig. 5F), producing “pipe rock.” The abundance of bioturbation activity suggests an environment favorable for organisms and the nature of the vertical burrows indicates high sedimentation rates as organisms constantly try to keep pace with the influx of sediment (Desjardins et al., 2010). This facies is interpreted as an upper shoreface environment with its abundant *Skolithos* burrows and poor preservation of primary structures (Reinson, 1984).

Facies E is a very fine to fine quartz arenite that has low-angle crossbedding and medium set bed thicknesses (Table 1). Facies E lacks horizontal or vertical bioturbation features. With a lack of bioturbation and well preserved crossbedding, this facies is interpreted as an upper shoreface/foreshore depositional environment (Reinson, 1984; Short, 1984).

RESULTS

The quartz arenite is further subdivided into two third-order sequences (Fig. 6). Shallowing upward trends based on facies relationships were used to identify the two internal third-order sequences. The basal and upper contact with the Garden City Limestone and Fish Haven Dolomite, respectively, mark regional unconformities and are third-order sequence boundaries.

Detrital Zircon Data

Two detrital zircon samples from the base and top of the Bear Lake section (Fig. 3A) were previously analyzed (Pope, 2008). In the basal sample, 116 detrital zircon grains have a bimodal age distribution with a main peak between 2.5 – 3.0 Ga and a smaller peak at 1.8 – 2.0 Ga. Most of the Archean grains are between 2.6 – 2.7 Ga with a very minor (2 grain) population between 0.8 – 1.2 Ga. The lower medial sample closest to the base, contains 81 total grains and has a main Archean (2.5 – 3.0 Ga) population and a smaller Paleoproterozoic (1.8 – 2.0 Ga) population. Most of the Archean grains in this analysis are between 2.6 – 2.7 Ga. The upper medial sample has 92 grains with a dominant Paleoproterozoic (1.8 – 2.0 Ga) population and a smaller Archean (2.5 – 3.0 Ga) population with the majority of the grains between 1.8 – 1.9 Ga. This upper medial sample also has one 1.1 Ga grain. The upper Bear Lake sample has 111 grains and most of those grains are between 1.8 – 2.0 Ga. A second, smaller population occurs at 2.5 – 3.0 Ga, with the smallest third population occurring between 2.0 – 2.1 Ga.

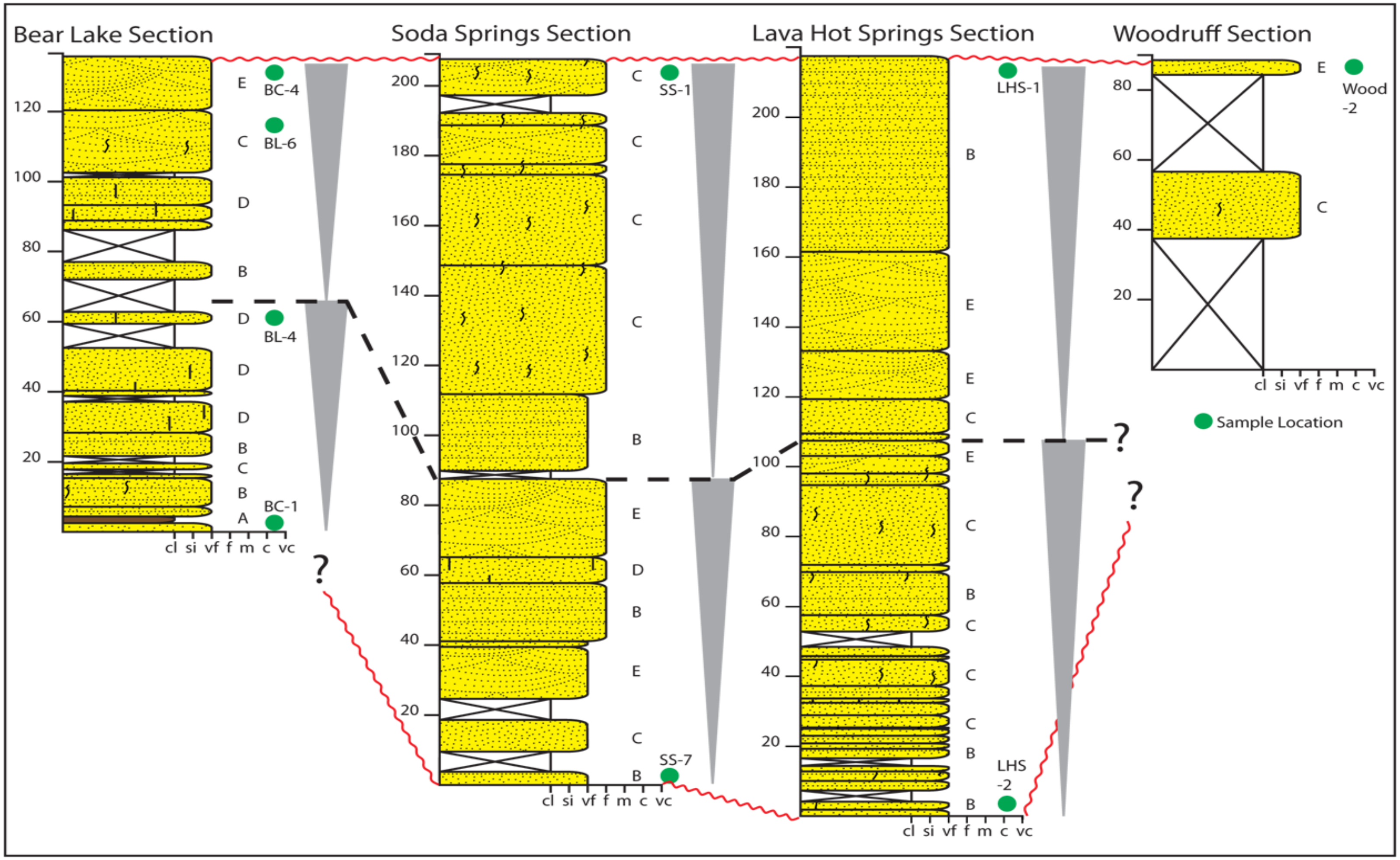


FIG. 6.—East to west cross-section of the Swan Peak Quartzite within the study area. Basal and upper contacts are unconformities marking sequence boundaries. An approximate 3rd –order sequence boundary is marked by the dashed line. Facies associations and detrital zircon samples are shown for each measured section. The gray triangles indicate shallowing upward successions within each section as delineated by facies.

The basal Soda Springs sample (Fig. 3A) has a dominant population between 2.5 – 3.0 Ga with a smaller population at 1.8 – 2.0 Ga. Forty-six of the 94 total grains in the basal sample are between 2.6 – 2.7 Ga. The upper Soda Springs sample has 85 zircon grains containing a large 1.8 – 2.0 Ga Paleoproterozoic population, a pronounced 2.0 – 2.1 Ga population, and a smaller 2.5 – 3.0 Ga Archean population. The majority of the grains in this sample occur between 1.8 – 1.9 Ga.

The basal Lava Hot Springs sample has detrital zircon ages of 2.5 – 3.0 Ga and 1.8 – 2.0 Ga from 76 total grains (Fig. 3A). The main population is the Archean (2.6 – 2.7 Ga) grains at the base of this unit. The upper sample of this section with its 89 zircon grains, has a trimodal distribution of age spectra between 1.8 – 2.0 Ga, 2.0 – 2.1 Ga, and 2.6 -2.7 Ga. Additionally, there are five 0.8 – 1.2 Ga grains at the top of the Lava Hot Springs section.

Ninety-one grains were analyzed from the sample near the top of the Woodruff section (Fig. 3A). Most of the grains are Paleoproterozoic (1.8 – 2.0 Ga), with a smaller peak at 2.0 – 2.1 Ga, and a minor Archean peak between 2.5 – 2.7 Ga. Two 0.8 – 1.2 Ga grains also occur in this sample.

DISCUSSION

Detrital Zircon Interpretation

The analyses from the detrital zircon samples can be grouped into four main populations for comparison. The smallest, and youngest, zircon population is between 0.8 – 1.2 Ga. This small Mesoproterozoic zircon population may coincide with various terranes sutured to the eastern margin of Laurentia that formed the supercontinent Rodinia (Hoffman, 1989; Tollo et al., 2004). Mesoproterozoic zircons indicate possible recycling of grains with westward long distance transport across the Laurentian craton (Rainbird et al., 1992; Rainbird et al., 1997). However, Mesoproterozoic metamorphism of the Belt Supergroup (1.4 – 1.7 Ga) was recently documented in northern Idaho and southern Montana, suggesting a local basement source rather than recycling and long distance transport across the continent (Vervoort et al., 2005; Nesheim et al., 2009).

A minor, but persistent, population of 2.0 – 2.1 Ga occurs in all the upper samples and the two medial Bear Lake samples. Basement rock of this age is currently unknown in North America (Whitmeyer and Karlstrom, 2007).

A prominent 1.8 – 2.0 Ga population occurs in nearly every sample. The upper parts of all sections generally are dominated by this population. These zircons are contemporaneous with the Trans-Hudson Orogeny, which sutured the Wyoming, Superior, and Hearne-Rae cratons to the western margin of Laurentia, forming the Canadian shield and much of the North American craton (Hollings and Ansdell, 2002; Ross and Eaton, 2002; Pope, 2008). The decrease in Archean grains within the upper samples suggests either the Archean source became partially covered, the sediment source switched to another location, or the source was reworked from the same provenance during the last depositional stage of this unit. The small population of 1.8 – 2.0 Ga Paleoproterozoic grains near the base of each section, and a much larger population near the top of each section also suggests a temporal change in provenance or source reworking from the same provenance.

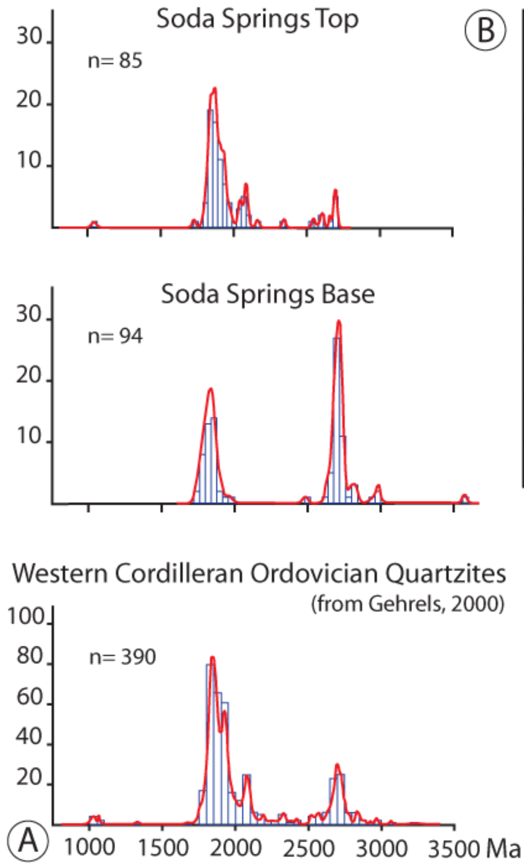
Archean (2.5 – 3.0 Ga) zircon grains are the other prominent population in these samples. A general trend in this population is that more grains of this range occur at the base of each section than at the top of the sections. A proximal Archean source possibly contributed sediment during this period of deposition. The Wyoming Craton (2.5 – 3.0 Ga) is a likely candidate for a source area as it contains appropriate age source rocks and its close proximity to the depositional locus of the Swan Peak Quartzite (Sims et al., 2001; Chamberlain et al., 2003; Foster et al., 2006; Mueller and Frost, 2006).

Previous work on similar Ordovician quartzites (Fig. 3B) along the Cordilleran margin also demonstrate the same four populations at 0.8 – 1.2 Ga, 1.8 – 2.0 Ga, 2.0 – 2.1 Ga, and 2.5 – 3.0 Ga (Gehrels and Dickinson, 1995; Gehrels et al., 1995; Gehrels, 2000, Gehrels pers. com., 2008). Unique to the Ordovician quartz arenite age spectra along the Laurentia passive margin is a lack of Cambrian and Neoproterozoic grains. Lack of abundant 1.4 – 1.7 Ga of the Belt Supergroup, and Neoproterozoic grains indicate little to no grain recycling of the underlying basement or Cambrian sandstones (Gehrels and Ross, 1998; Gehrels, 2000). At the base of the Swan Peak Quartzite sections, no grain recycling is apparent since no Neoproterozoic or Cambrian zircon age populations were detected. Some grain recycling may occur at the tops of the sections as recorded by the younger Mesoproterozoic population, which may have been transported across the Laurentia craton (Rainbird et al., 1992; Rainbird et al., 1997).

The Swan Peak zircon analyses were compared for overlap and similarity (Gehrels, 2000) against the Cordilleran Ordovician quartz arenites data (Gehrels et al., 1995, Gehrels, 2000; Gehrels pers. com., 2008). Determining the overlap and similarity between the data sets was accomplished by using an overlap-similarity program (Gehrels, 2011). Overlap compares two samples to determine if they have the same age populations while ignoring the proportion of grains; similarity compares the ages in two samples factoring in the proportion of similar age populations (Gehrels, 2000). The zircon data of this study (Fig. 7) overlap with the previous analyses on the Cordilleran quartz arenites (Gehrels, 2000; Gehrels pers. com., 2008) with a range of 0.531 – 0.771, and similarity proportions have a range between 0.506 – 0.881. Overall, the upper parts of the measured sections in this study have better overlap and similarity values (Gehrels, 2000) than the base of each section. The zircon age spectra and overlap and similarity values from the Swan Peak Quartzite are consistent with other quartz arenites sampled across the Cordilleran margin, with almost all the samples containing the same four zircon populations (e.g. Gehrels and Dickinson, 1995; Gehrels et al., 1995; Gehrels, 2000; Baar, 2008). Hence, the provenance for the Swan Peak Quartzites can be compared to known provinces along the Cordilleran margin.

Implications

The provenance for the Middle-Late Ordovician quartz arenites along the



B

Sample	Overlap	Similarity
Wood 2 Top	0.710	0.863
BC 4 Top	0.753	0.849
BL 6	0.771	0.811
BL 4	0.741	0.651
BC 1 Base	0.531	0.506
SS 2 Top	0.711	0.881
SS 7 Base	0.603	0.687
LHS 1 Top	0.757	0.803
LHS 2 Base	0.597	0.662

FIG. 7.—A. Swan Peak Quartzite detrital zircons are compared against a composite Middle-Late Ordovician quartz arenite sample of the Cordilleran margin (Gehrels pers. com., 2008). The graphs illustrate the comparison of overlap and similarity of one measured section in this study to the reference curve previously generated. B. Table of overlap and similarity values for the Swan Peak Quartzite grains. These values are consistent with previous work by Gehrels (2000).

western Cordilleran margin was previously hypothesized to come primarily from the Peace River Arch, transported by longshore currents (Gehrels and Dickinson, 1995; Gehrels et al., 1995; and Gehrels, 2000). However, it appears that proximal sources may play a bigger role in the local delivery of sediment to this passive margin (Fig. 8). The Wyoming Craton, predominantly 2.5 – 3.0 Ga (Sims et al., 2001; Chamberlain et al., 2003; Foster et al., 2006; Mueller and Frost, 2006), is the likely source area for the lower portions of Swan Peak Quartzite sections. The zircon analyses of this study suggest that the Trans-Hudson Orogen and the Wyoming Craton provided most of the sediment for the Swan Peak Quartzite.

Provenance changes in the Swan Peak Quartzite are postulated to coincide with long-term (m.y.) sea level rises and falls. The base of each section has a preponderance of Archean (2.5 – 3.0 Ga) grains, whereas the top of the sections has a greater abundance of Paleoproterozoic (1.8 – 2.0 Ga) grains. Relative sea level was at its lowest extent in the Middle Ordovician during a second-order lowstand that marks the Sauk-Tippecanoe boundary (Read, 1989; Haq and Schutter, 2008). When sea level was low (Fig. 9), the Transcontinental Arch, a positive feature of exposed crystalline basement rocks in the interior of Laurentia, provided sediment for the Middle-Late Ordovician quartz arenites and quartzites (Witzke, 1980; Witzke, 1990). Many of the Middle-Late Ordovician quartz arenites of North America formed during this lowstand or the subsequent transgression as sea level rose during the Tippecanoe sequence to cover much of the continent (Haq and Schutter, 2008).

During the transgressive systems tract (TST), relative sea level rose, flooding the

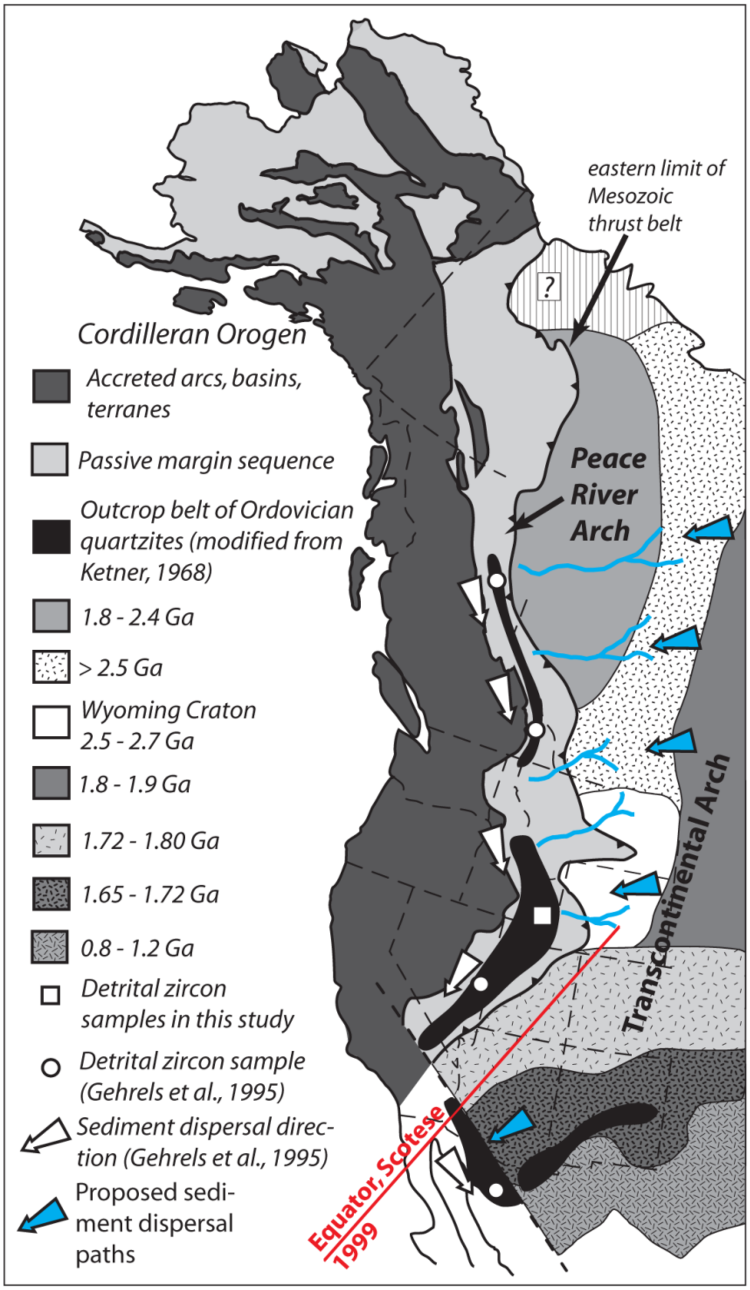


FIG. 8.—Outcrops of Middle-Late Ordovician quartz arenites plotted on the Paleozoic passive margin (modified from McClelland, unpub.). Basement units are from Hoffman (1989), Ross and Villeneuve (2003), Van Schmus et al. (1993), and Whitmeyer and Karlstrom (2007). Previous detrital zircon studies indicate that Middle-Late Ordovician quartz arenites of western North America have a unique provenance dominated by 1.8-2.0 Ga and 2.5-2.8 Ga grains with another small, but persistent population of 2.1 Ga grains (Gehrels and Dickinson, 1995; Gehrels, 2000). Rare 0.8-1.2 Ga grains occur locally. These studies indicate a uniform source area with little recycling of underlying Mesoproterozoic, Neoproterozoic, or Cambrian sandstones that contain a wide array of 0.6-1.7 Ga grains derived from North American basement sources (Ross et al., 1992; Gehrels and Ross, 1998; Ross and Villeneuve, 2003).

Laurentian continent (Fig. 9). Initially, the proximal basement source likely provided the bulk of the sediment for the Swan Peak Quartzite. However, as sea level continued to rise, the proximal source areas for sediment were no longer subaerially exposed, being buried by sediment or water. Therefore, sediment supply during the later TST was supplied primarily from basement sources farther inland, presumably the Trans-Hudson Orogen.

During the highstand systems tract (HST), sea level rise decreased and eventually began to fall (Fig. 9), causing siliciclastic sediments deposited during the HST to prograde basinward. Sediment for these units were derived from the Trans-Hudson Orogeny and possibly from later TST shelf deposits. However, small amounts of Archean grains in the upper sections of the Swan Peak Quartzite indicate the Wyoming Craton did not provide the bulk of the sediment during later deposition.

The preponderance of the four distinct zircon populations (0.8 – 1.2 Ga, 1.8 – 2.0 Ga, 2.0 – 2.1 Ga, and 2.5 – 3.0 Ga) in Middle-Late Ordovician quartz arenites indicates they all had similar sources. No populations of younger Paleoproterozoic-Mesoproterozoic (1.4 – 1.7 Ga) grains, which are ubiquitous in the Belt Supergroup (Ross et al., 1992; Ross and Villeneuve, 2003), were detected in the Swan Peak analyses, suggesting this was not a significant source of sediment during the Middle-Late Ordovician. The tops of the samples have the anomalous 2.0 – 2.1 Ga peak and may indicate minor recycling during the HST, although the source for these grains is currently undetermined. Additionally, Mesoproterozoic grains may be coming from across the Laurentian margin contributing to minor grain recycling (Rainbird et al.,

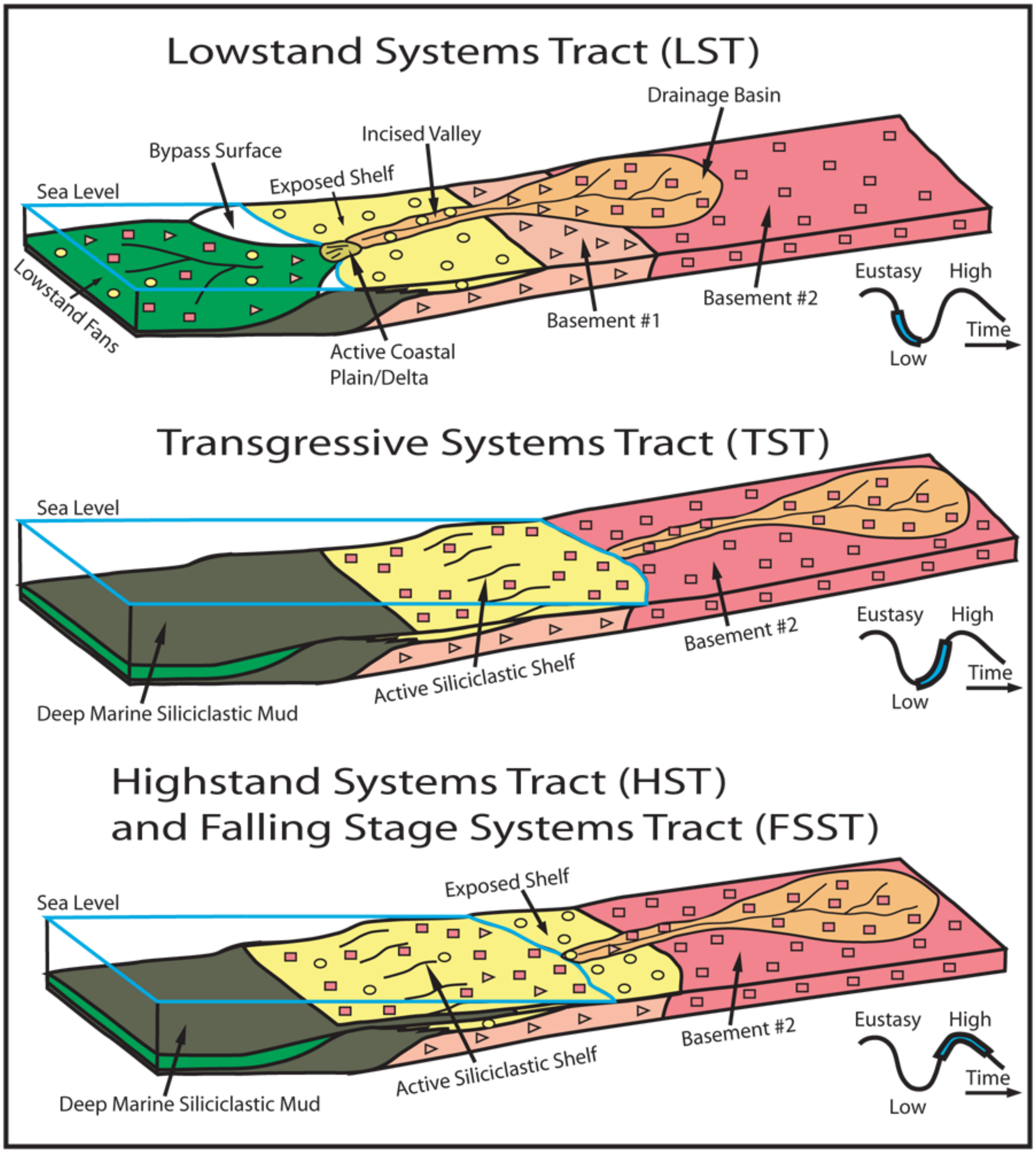


Fig. 9.—An illustration of how the siliciclastic source areas may change during long-term relative sea level fluctuations. The different shapes represent different sources of sand-sized detritus (siliciclastic shelf – circles; Basement #1 – triangles; Basement #2 – squares). During the LST (upper) when sea level is low, the siliciclastic shelf is subaerially exposed and erosion within the incised valley provides a source of sediment for the coastal plain/delta or lowstand fans. As relative sea level rises during the TST (middle) the underlying shelf and much of the local basement (Basement #1) is buried by sediment derived from Basement #2 or farther inland. As relative sea level begins to fall during the HST or FSST (lower) siliciclastic detritus come increasingly from proximal sources including recycled TST shelf deposits.

1992; Rainbird et al., 1997), or from local Mesoproterozoic metamorphism in Idaho and Montana (Vervoort et al., 2005; Nesheim et al., 2009). The lack of grain recycling was likely a result of extreme chemical weathering near the paleoequator, generating abundant first-cycle quartz arenites (Johnsson et al., 1988). Rapid sea level rise or high sedimentation rates may have prevented Cambrian and older Proterozoic sedimentary rocks from providing detritus to the Middle-Late Ordovician passive margin.

The position of the Transcontinental Arch relative to the paleoequator and the abundance of detrital zircon grains from the Trans-Hudson Orogeny suggest the Transcontinental Arch was the most likely sediment source during the Middle-Late Ordovician. Support for this is a general lack of sediment recycling, implying the grains may have a more proximal transport path, and the abundance of grains from a proximal basement source. Rivers draining off the Transcontinental Arch likely supplied the majority of the sediment for the Middle-Late Ordovician quartz arenites deposited along the passive margin shoreline (Fig. 8). Longshore transport was likely an important process in redistributing the grains along the coastline (Ketner, 1968, Gehrels, 2000) and explains the similarity of quartz arenite provenance along the Cordilleran margin.

CONCLUSIONS

Middle-Late Swan Peak Quartzite is a supermature quartz arenite deposited along the western Paleozoic Laurentian passive margin. This unit consists of very fine- to fine-grained, well-rounded, well-sorted, and silica cemented quartz arenite deposited in offshore to onshore (distal shallow shelf to upper shoreface/beach) environments. The humid equatorial climate during the Middle-Late Ordovician supplied ample siliciclastic sediment from basement areas along the Transcontinental Arch to the Laurentian passive margin.

Basal and upper contacts with Garden Creek Limestone and Fish Haven Dolomite, respectively, mark regional unconformities and are third-order sequence boundaries. Two internal third-order sequences within the Swan Peak Quartzite were determined on shallowing upward facies trends.

The Swan Peak Quartzite can be subdivided into five major facies (A – E) along an offshore-to-onshore transect. Facies A is interpreted to be storm deposits on the distal shallow shelf. This facies only occurs at the base of the Bear Lake section and was likely deposited in an incised valley or local embayment. Facies B through E record lower to upper shoreface/foreshore depositional environments.

Zircon age spectra from each section have similar signatures. Four main zircon populations occur at 0.8 – 1.2 Ga, 1.8 – 2.0 Ga, 2.0 – 2.1 Ga, and 2.5 – 3.0 Ga. At the base of each section the dominant population is Archean with a more subdued Paleoproterozoic population with few to no Grenville grains or 2.0 – 2.1 Ga grains. The top of each section has a greater abundance of Paleoproterozoic grains, a persistent 2.0 – 2.1 Ga population, a smaller Archean population, and common, though few, 0.8 – 1.2 Ga grains in each sample.

The Transcontinental Arch was subjected to intense, humid equatorial weathering, which provided the sediment for the Middle-Late Ordovician quartz arenites surrounding this positive feature. Provenance changes occurred as sea level fluctuated. Maximum basement exposure occurred during the LST, or base of the TST in the Swan Peak Quartzite, when the Wyoming Craton was the most proximal source of sediment. As sea level continued to rise during the TST, proximal source areas were buried with sediment or covered by water. Siliciclastic sediment was sourced from a more distal basement source, such as the 1.8 – 2.0 Ga Trans-Hudson Orogen, during the HST. Siliciclastic sediment deposited during the HST prograded basinward. Provenance for the HST sediments came first from recycled TST shelf deposits and distal sources on the Transcontinental Arch. Increased re-working and recycling may have tapped into previously buried proximal sediment sources. Longshore currents were important in moving sediments along the Laurentian shoreline, producing a homogenous succession of rocks with unique and laterally similar detrital zircon age populations.

REFERENCES

Arnott, R.W.C., 1993, Quasi-planar-laminated sandstone beds of the Lower Cretaceous Bootlegger Member, north-central Montana: Evidence of combined-flow sedimentation: Journal of Sedimentary Petrology, v. 63, p. 488-494.

Baar, E., 2008, Regional scale detrital zircon provenance study of the Middle to Late Ordovician Eureka Quartzite, east-central Idaho: Geological Society of America Abstract with Programs, v. 40, p. 57.

Beus, S.S., 1968, Paleozoic Stratigraphy of Samaria Mountain Idaho-Utah: American Association of Petroleum Geologists Bulletin, v. 52, p. 782-808.

Biek, R.F., 1999, Geology of Clarkston Mountain (southern Malad Range), Box Elder and Cache Counties, Utah: Utah Geological Association Publication 27, p. 27-44.

Blakey, R.C., 2011, Paleogeographic plate reconstructions, accessed on August, 2011, http://www2.nau.edu/rcb7/globaltext2.html.

Chamberlain, K.R., Frost, C.D., and Frost, B.R., 2003, Early Archean to Mesoproterozoic evolution of the Wyoming Province: Archean origins to modern lithospheric architecture: Canadian Journal of Earth Sciences, v. 40, p. 1357-1374.

Chandler, F.W., 1988, Quartz arenites: Review and interpretation: Sedimentary Geology, v. 58, p. 105-126.

Chang, Z., Vervoort, J.D., Knaack, C., and McClelland, W.C., 2006, U-Pb dating of zircon by LA-ICPMS: Geochemistry, Geophysics, Geosystems, v. 7, no. 5, p. 1-14, Q05009, doi:10.1029/2005GC001100.

Churkin, M. Jr., 1962, Facies across Paleozoic miogeosynclinal margin of central Idaho: American Association of Petroleum Geologists Bulletin, v. 46, p. 569-591.

Dapples, E.C., 1955, General lithofacies relationship of St. Peter Sandstone and Simpson Group: American Association of Petroleum Geologists Bulletin, v. 39, p. 444-467.

Davis, D.W., Hirdes, W., Schaltegger, U., and Nunoo, E.A., 1994, U-Pb age constraints on deposition and provenance of Birmian and gold-bearing Tarkwaian sediments in Ghana, West Africa: Precambrian Research, v. 67, p. 89-107.

DESJARDINS, P.R., MÁNGANO, M.G., BUATOIS, L.A., PRATT, B.R., 2010, Skolithos pipe rock and associated ichnofabrics from the southern Rocky Mountains, Canada: Colonization trends and environmental controls in an early Cambrian sand-sheet complex: Lethaia, v. 43, p. 507-528.

DODSON, M.H., COMPSTON, W., WILLIAMS, I.S., and WILSON, J.F., 1988, A search for ancient detrital zircons in Zimbabwean sediments: Journal of the Geological Society of London, v. 145, p. 977-983.

DOTT, R.H.JR., 2003, The importance of eolian abrasion in supermature quartz sandstones and the paradox of weathering on vegetation-free landscapes: Journal of Geology, v. 111, p. 387-405.

DOTT, R.H.JR., and BOURGEOIS, J., 1982, Hummocky stratification: Significance of its variable bedding sequences: Geological Society of America Bulletin, v. 93, p. 663-680.

DOTT, R. H.JR., BYERS, C.W., FIELDER, G.W., STENZEL, S.R., and WINFREE, K.E., 1986, Aeolian to marine transition in Cambro-Ordovician cratonic sheet sandstones of the northern Mississippi valley, U.S.A.: Sedimentology, v. 33, p. 345-367.

DRUSCHKE, P.A., JIANG, G., ANDERSON, T.B., and HANSON, A.D., 2009, Stromatolites in the late Ordovician Eureka Quartzite: Implications for microbial growth and preservation in siliciclastic settings: Sedimentology, v. 56, p. 1275-1291.

DUTTA, P.K., and SUTTNER, L.J., 1981, Fluvial sandstone composition and paleoclimate *in* Collinson, J.D., and Lewin, J., eds., Modern and Ancient Fluvial Systems: Keele, United Kingdom, p. 34-47.

FEDO, C. M., SIRCOMBE, K.N., RAINBIRD, R.H., 2003, Detrital zircon analysis of the sedimentary record, *in* Hanchar, J.M., and Hoskin, P.W.O., eds., Zircon, Reviews in Mineralogy and Geochemistry, v. 53, p. 277-303.

FOSTER, D.A., MUELLER, P.A., MOGK, D.W., WOODEN, J.L., VOGL, J.J., 2006, Proterozoic evolution of the western margin of the Wyoming craton: Implications for the tectonic and magmatic evolution of the northern Rocky Mountains: Canadian Journal of Earth Sciences, v. 43, p. 1601-1619.

GEHRELS, G.E., 2000, Introduction to detrital zircon studies of Paleozoic and Triassic strata in western Nevada and northern California, *in* Soreghan, M.J., and Gehrels, G.E., eds., Paleozoic and Triassic Paleogeography and Tectonics of Western Nevada and Northern California: Boulder, CO, Geological Society of America Special Paper 347, p. 1-17.

GEHRELS, G.E., 2011, Overlap and similarity program, Accessed on June, 2011, https://sites.google.com/a/laserchron.org/laserchron/home.

GEHRELS, G.E., and DICKINSON, W.R., 1995, Detrital zircon provenance of Cambrian to Triassic miogeoclinal and eugeoclinal strata in Nevada: American Journal of Science, v. 295, p. 18-48.

GEHRELS, G.E., DICKINSON, W.R., ROSS, G.M., STEWART, J.H., and HOWELL, D.G., 1995, Detrital zircon reference for Cambrian to Triasssic miogeoclinal strata of western North America: Geology, v. 23, p. 831-834.

GEHRELS, G.E., and ROSS, G.M., 1998, Detrital zircon geochronology of Neoproterozoic to Permian miogeoclinal strata in British Columbia and Alberta: Canadian Journal of Earth Sciences, v. 35, p. 1380-1401.

GRADSTEIN, F.M., OGG, J.G., and SMITH, A.G., 2004, A Geologic Time Scale 2004: University Press, Cambridge, United Kingdom.

GREENWOOD, B., and MITTLER, P.R., 1985, Vertical sequence and lateral transitions in the facies of a barred nearshore environment: Journal of Sedimentary Research, v. 55, p. 366-375.

HALL, C.D., 1989, Storm bedding in the Middle Ordovician Kinnikinic Quartzite, Beaverhead Range, east central Idaho: Geological Society of America Abstracts with Programs, v. 21, p. 88-89.

HAQ, B.U., and SCHUTTER, S.R., 2008, A chronology of Paleozoic sea-level changes: Science, v. 322, p. 64-68.

HARRIS, A.G., BERGSTROM, S.M., ETHINGTON, R.L., and ROSS, R.J.JR., 1979, Aspects of Middle and Upper Ordovician conodont biostratigraphy of carbonate facies in Nevada and southeast California and comparison with some Appalachain successions, *in* Sandberg, C.A., and Clark, D.L., eds., Conodont biostratigraphy of the Great Basin and Rocky Mountains, BYU Geology Studies, v. 26, p. 7-44.

HARRIS, M.T., SEXTON, L.A., and SHEEHAN, P.M., 1995, Depositional facies and sequences of upper Ordovician shelf and shallow ramp carbonates of the eastern great basin (Utah and Nevada), U.S.A. Ordovician Odyssey: Short Papers for the Seventh International Symposium on the Ordovician System, p. 265-266.

HISCOTT, R.N., 2001, Depositional sequences controlled by high rates of sediment supply, sea-level variations, and growth faulting: the Quaternary Baram Delta of northwestern Borneo: Marine Geology, v. 175, p. 67-102.

HOBBS, S.W., HAYS, W.H., and ROSS, R.J., 1968, The Kinnikinic Quartzite of central Idaho – Redefinition and subdivision: United States Geological Survey Bulletin 1254-J, p. J1-J22.

HOFFMAN, P.F., 1989, Precambrian geology and tectonic history of North America, *in* Bally, A.W., and Palmer, A.R., eds., The Geology of North America – An Overview: Boulder Colorado, Geological Society of America, Geology of North America 1989, v. A, p. 447 - 512.

HOLLINGS, P., and ANSDELL, K., 2002, Paleoproterozoic arc magmatism imposed on an older backarc basin: Implications for the tectonic evolution of the Trans-Hudson orogeny, Canada: Geological Society of America Bulletin, v. 114, p. 153-168.

JAMES, W.C., and OAKS, R.Q., 1977, Petrology of the Kinnikinic Quartzite (Middle Ordovician), east-central Idaho: Journal of Sedimentary Petrology, v. 47, p. 1491-1511.

JOHNSSON, M.J., STALLARD, R.F., and MEADE, R.H., 1988, First-cycle quartz arenites in the Orinoco River basin, Venezuela and Colombia: Journal of Geology, v. 96, p. 263-277.

KETNER, K.B., 1968, Origin of Ordovician Quartzite in the Cordilleran Miogeosyncline: United States Geological Survey Professional Paper 600-B, p. B169-B177.

LEATHAM, W.B., 1985, Ages of the Fish Haven and lowermost Laketown dolomites in the Bear River Range, Utah, *in* Kerns, G.J., and Kerns, R.L., eds., Orogenic Patterns and Stratigraphy of North Central Utah and Southeastern Idaho, p. 29-38.

LESLIE, S.A., and LEHNERT, O., 2005, Middle Ordovician (Chazyan) sea-level changes and then evolution of the Ordovician conodont genus *Cahabagnathus* Bergstroem: Journal of Paleontology, v. 79, p. 1131-1142.

LINK, P.K., 2007, Detrital zircon populations and provenance of Mesoproterozoic strata of east-central Idaho, U.S.A.: Correlation with Belt Supergroup of southwest Montana: Society for Sedimentary Geology Special Publication, v. 86, p. 101-128.

LINK, P.K., and JANECKE, S.U., 1999, Geology of east-central Idaho: geologic roadlogs for the Big and Little Lost Rivers, Lemhi, and Salmon River Valleys, *in* Hughes, S.S., Thckray, G.D., eds., Guidebook to the Geology of Eastern Idaho: Idaho Museum of Natural History, Pocatello, ID, p. 295-334.

LUDWIG, K.R., 2003, User's Manual for Isoplot 3.00. A Geochronological toolkit for Microsoft Excel. Berkeley Geochronology Center, Special Publication No. 4.a, Berkeley, CA.

MCLAUGHLIN, P.I., BRETT, C.E., MCLAUGHLIN, S.L.T., and CORNELL, S.R., 2004, High-resolution sequence stratigraphy of a mixed carbonate-siliciclastic, cratonic ramp (Upper Ordovician; Kentucky-Ohio, USA): Insights into the relative influence of eustasy and tectonics through analysis of facies gradients: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 210, p. 267-294.

MEASURES, E.A., 1992, Stratigraphy, carbonate lithologies, and depositional environments of Upper Ordovician Fish Haven Dolomite and Saturday Mountain Formation, east-central and central Idaho, and implications for platform development and margin tectonics: Unpublished Ph.D. Dissertation, University of Idaho, Moscow, ID, p. 1-535.

MIDTGAARD, H.H., 1996, Inner-shelf to lower-shoreface hummocky sandstone bodies with evidence for geostrophic influenced combined flow, Lower Cretaceous, West Greenland: Journal of Sedimentary Research, v. 66, p. 343-353.

MUELLER, P.A., and FROST, C.D., 2006, The Wyoming Province: A distinctive Archean craton in Laurentian North America: Canadian Journal of Earth Sciences, v. 43, p. 1391-1397.

NESHEIM, T.O., GILOTTI, J.A., MCCLELLAND, W.C., LANG, H.M., VERVOORT, J.D., TEFFT, A. M., and FOSTER, C.T.JR., 2009, Evidence of Grenville-Age deformation and metamorphism in Belt Supergroup metapelites of Northern Idaho: Geological Society of America Abstracts with Programs, v. 41, p. 181.

NORFORD, B.S., 1969, Ordovician and Silurian stratigraphy of the southern Rocky Mountains: Geological Survey of Canada Bulletin, v. 176, p. 1-90.

OAKS, R.Q., and JAMES, W.C., 1980, The Kinnikinic Quartzite (Middle Ordovician) in the type area, central Idaho, and a new reference section near Arco, Idaho: Geology Studies, v. 27, p. 1-9.

POOLE, F.G., STEWART, J.H., REPETSKI, J.E., HARRIS, A.G., ROSS, R.J.JR, KETNER, K.B., AMAYA-MARTINEZ, R., and MORALES-RAMIREZ, J.M., 1995, Ordovician carbonate-shelf rocks of Sonora, Mexico: Ordovician Odyssey: Short Papers for the Seventh International Symposium on the Ordovician System, book 77, p. 267-275.

POPE, M.C., 2008, Detrital zircon geochronology of Late Ordovician sandstone in Wyoming suggest Talson-Thelon Orogen was a major source of siliciclastic sediment along the Transcontinental Arch: Geological Society of America Abstracts with Programs, v. 40, p. 77.

RAINBIRD, R.H., HEAMAN, L.M., and YOUNG, G., 1992, Sampling Laurentia: Detrital zircon geochronology offers evidence for an extensive Neoproterozoic river system originating from the Grenville Orogen: Geology, v. 20, p. 351-354.

RAINBIRD, R.H., MCNICOLL, V.J., THERIAULT, R.J., HEAMAN, L.M., ABBOTT, J.G., LONG, D.G.F., and THORKELSON, D.J., 1997, Pancontinental river system draining Grenville orogeny recorded by U-Pb and Sm-Nd geochronology of Neoproterozoic quartz arenites and mudrocks, northwestern Canada: Journal of Geology, v. 105, p. 1-17.

READ, J.F., 1989, Evolution of Cambro-Ordovician passive margin, U.S. Appalachians, *in* Hatcher, R.D. JR., Thomas, W.A., and Viele, G.W., eds., The Appalachian-Ouchita Orogeny in the United States: Boulder, Colorado, p. 42-57.

REINSON, G.E., 1984, Barrier-island and associated strand-plain systems, *in* Walker, R.G., ed., Facies Models, 2nd ed.: Geoscience Canada Reprint Ser. 1, p. 119-140.

ROBACK, R.C., and WALKER, N.W., 1995, Provenance, detrital zircon U-Pb geochronometry, and tectonic significance of Permian to Lower Triassic sandstone in southeastern Quesnellia, British Columbia and Washington: Geological Society of America Bulletin, v. 107, p. 665-675.

ROSS, G.M., and EATON, D.W., 2002, Proterozoic tectonic accretion and growth of western Laurentia: Results from Lithoprobe studies in northern Alberta: Canadian Journal of Earth Science, v. 39, p. 313-329.

ROSS, G.M., PARRISH, R.R., WINSTON, D., 1992, Provenance and U-Pb geochronology of the Mesoproterozoic Belt Supergroup (northwestern United States): Implications for age of deposition and pre-Panthalassa plate reconstructions: Earth and Planetary Science Letters, v. 113, p. 57-76.

ROSS, G.M. and VILLENEUVE, M., 2003, Provenance of the Mesoproterozoic (1.45 Ga) Belt basin (western North America): Another piece in the pre-Rodinia paleogeographic puzzle: Geological Society of America Bulletin, vol. 115, 1191-1217.

ROSS, R.J., 1959, Brachiopod fauna of Saturday Mountain Formation, southern Limhi Range, Idaho: United States Geological Survey Professional Paper 294-L, p. 441-461.

Ross, R.J., 1961, Distribution of Ordovician graptolites in eugeosynclinal facies in western North America and its paleogeographic implications: American Association of Petroleum Geologists Bulletin, v. 45, p. 330-341.

Runkel, A.C., Miller, J.F., McKay, R.M., Palmer, A.R., and Taylor, J.F., 2007, High-resolution sequence stratigraphy of lower Paleozoic sheet sandstones in central North America: The role of special conditions of cratonic interiors in development of stratal architecture: Geological Society of America Bulletin, v. 119, p. 860-881.

Ruppel, E.T., Ross, R.J., and Schleicher, D., 1975, Precambrian Z and Lower Ordovician rocks in east-central Idaho: United States Geological Survey Professional Paper 889-B, p. 25-34.

Saltzman, C.R., and Young, S.A., 2005, A long-lived glaciation in the Late Ordovician? Isotopic and sequence-stratigraphy evidence from western Laurentia: Geology, v. 113, p. 109-112.

Scotese, C.R., 2002, Paleomap reconstructions, accessed on June, 2011, http://www.scotese.com.

Scotese, C.R., Boucot, A.J., and McKerrow, W.S., 1999, Gondwanan palaeogeography and palaeoclimatology: Journal of African Earth Sciences, v. 29, p. 99-114.

Scott, D.J., and Gauthier, G., 1996, Comparison of TIMS (U-Pb) and laser ablation microprobe ICP-MS (Pb) techniques for age determination of detrital zircons from Paleoproterozoic metasedimentary rocks from northeastern Laurentia, Canada, with tectonic implications: Chemical Geology, v. 131, p. 127-142.

Short, A.D., 1984, Beach and nearshore facies: southeast Australia: Marine Geology, v. 60, p. 261-282.

Sims, P.K., Finn, C.A., and Rystrom, V.L., 2001, Preliminary Precambrian basement map showing geologic—geophysical domains, Wyoming: U.S. Geological Survey, Open-File Report 2001–199, p. 1-9.

Sircombe, K.N., 2000, Quantitative comparison of geochronological data using multivariate analysis: a provenance study example from Australia: Geochemica Cosmochimica Acta, v. 64. p. 1593-1619.

Sloss, L.L., 1954, Lemhi Arch, a mid-Paleozoic positive element in south-central Idaho: Geological Society of America Bulletin, v. 65, no. 4, p. 385-368.

SUHM, R.W., 1997, Simpson Stratigraphy of the southern midcontinent: Oklahoma Geological Survey Circular, v. 99, p. 3-38.

SWEET, W.C., 2000, Conodonts and biostratigraphy of Upper Ordovician strata along a shelf to basin transect in Central Nevada: Journal of Paleontology, v. 74, p. 1148-1160.

TOLLO, R.P., CORRIVEAU, L., MCLELLAND, J., BARTHOLOMEW, M.J., 2004, Proterozoic tectonic evolution of the Grenville orogeny in North America: An introduction, *in* Tollo, R.P., Corriveau, L., McLelland, J., James et al., eds., Proterozoic Tectonic Evolution of the Grenville Orogeny in North America: Geological Society of America Memoir 197, Boulder, CO, p. 1-18.

VAN DE KAMP, P.C., 2010, Arkose, subarkose, quartz sand, and associated muds derived from felsic plutonic rocks in glacial to tropical humid climates: Journal of Sedimentary Research, v. 80, p. 895-918.

VAN DER VOO, R., 1993, Paleomagnetism of the Atlantic, Tethys, and Iapetus oceans: University Press, Cambridge, United Kingdom.

VAN SCHMUS, W.R., BICKFORD, M.E., and CONDIE, K.C., 1993, Early Proterozoic transcontinental orogenic belts in the United States: Geological Society of America Abstracts with Programs, v. 25, p. 44.

VAN WAGONER, J.C., 1995, Sequence stratigraphy and marine to nonmarine facies architecture of foreland basin strata, Book Cliffs, Utah, U.S.A.: American Association of Petroleum Geologist Memoir 64, p. 137-223.

VERMEESCH, P., 2004, How many grains are needed for a provenance study?: Earth and Planetary Science Letters, v. 224, p. 441-451.

VERVOORT, J.D., MCCLELLAND, W.C., OLDOW, J.S., WATKINSON, A.J., and SHA, G.S., 2005, Grenville-age metamorphism on the western margin of Laurentia, northern Idaho: Evidence from Lu-Hf garnet geochronology: Geological Society of America Abstracts with Programs, v. 37, p. 89.

WEBB, G.W., 1958, Middle Ordovician stratigraphy in eastern Nevada and western Utah: American Association of Petroleum Geologists Bulletin, v. 42, no. 10, p. 2335-2377.

WHITMEYER, S.J., and KARLSTROM, K.E., 2007, Tectonic model for the Proterozoic growth of North America: Geosphere, v. 3, p. 220-259.

WITZKE, B.J., 1980, Middle and Upper Ordovician paleogeography of region bordering Transcontinental Arch: American Association of Petroleum Geologists Bulletin, v. 64, p. 805.

WITZKE, B.J., 1990, Paleoclimatic constraints for Paleozoic paleolatitudes of Laurentia and Euramerica: Geological Society of London Memoirs, v. 12, p. 57-73.

ZIMMERMAN, M.K., and COOPER, J.D., 1999, Sequence stratigraphy of the Eureka Quartzite in the southern Nevada and eastern California: Acta Universitatis Carolinae, Geologica, v. 43, p. 147-150.

APPENDIX A

SITE COORDINATES

Location	Latitude (N)	Longitude (W)	UTM Zone	Easting	Northing
Bear Lake (BL)	42° 05' 52"	111° 30' 29"	12 T	458041	4660572
Soda Springs (SS)	42° 40' 07"	111° 40' 22"	12 T	444918	4724030
Lava Hot Springs (LHS)	42° 36' 14"	111° 55' 58"	12 T	423544	4717051
Lava Hot Springs Road Cut 1 (LHS 1)	42° 37' 15"	111° 55' 54"	12 T	423659	4718945
Lava Hot Springs Road Cut 2 (LHS 2)	42° 37' 12"	111° 56' 22"	12 T	423020	4718853
Downey (D)	42° 32' 24"	112° 04' 06"	12 T	412334	4710088
Elkhorn Peak (EP)	42° 17' 30"	112° 16' 27"	12 T	395016	4682767
Woodruff (W)	42° 00' 02"	112° 16' 03"	12 T	395088	4650412

Reference datum is North American Datum of 1927 (NAD 27).

APPENDIX B

BEAR LAKE SECTION

DATA TABLES

C-1 Bear Lake Base

Sample	$^{238}U/^{206}PB$	1σ (%)	$^{207}Pb/^{206}PB$	1σ (%)	$^{238}U/^{206}PB$ Age (Ma)	1σ	$^{207}Pb/^{206}PB$ Age (Ma)	1σ
			Bear Lake (Base) <10% Discordant					
BC1_1	5.39	0.0140	0.0747	0.0068	1098	14	1061	14
BC1_2	1.98	0.0164	0.1793	0.0067	2634	35	2647	11
BC1_3	3.01	0.0131	0.1135	0.0052	1848	21	1856	9
BC1_4	1.89	0.0160	0.1832	0.0072	2740	36	2682	12
BC1_5	1.92	0.0141	0.1919	0.0056	2706	31	2758	9
BC1_6	2.19	0.0141	0.1747	0.0055	2421	28	2603	9
BC1_7	1.79	0.0133	0.2017	0.0048	2866	31	2840	8
BC1_8	2.90	0.0157	0.1164	0.0085	1909	26	1901	15
BC1_9	3.00	0.0131	0.1137	0.0053	1852	21	1859	10
BC1_10	3.01	0.0146	0.1132	0.0065	1848	23	1851	12
BC1_11	1.91	0.0118	0.1847	0.0044	2712	26	2695	7
BC1_12	1.69	0.0141	0.2038	0.0059	2992	34	2857	10
BC1_13	1.91	0.0126	0.1861	0.0047	2720	28	2708	8
BC1_14	1.96	0.0176	0.1829	0.0089	2658	38	2679	15
BC1_15	1.95	0.0139	0.1878	0.0071	2672	30	2723	12
BC1_16	1.96	0.0135	0.1778	0.0052	2653	29	2632	9
BC1_17	1.91	0.0128	0.1862	0.0050	2715	28	2709	8
BC1_18	1.98	0.0240	0.1848	0.0065	2633	52	2696	11
BC1_19	1.91	0.0114	0.1903	0.0044	2718	25	2745	7
BC1_20	1.89	0.0115	0.1892	0.0043	2741	26	2735	7
BC1_21	2.02	0.0146	0.1834	0.0081	2595	31	2683	13
BC1_22	1.67	0.0123	0.2195	0.0046	3019	30	2977	7
BC1_23	1.97	0.0129	0.1864	0.0052	2643	28	2710	9
BC1_24	2.90	0.0153	0.1130	0.0076	1907	25	1849	14
BC1_25	2.17	0.0144	0.1853	0.0044	2440	29	2701	7
BC1_26	1.84	0.0203	0.2084	0.0081	2804	46	2893	13
BC1_27	1.81	0.0175	0.1976	0.0059	2835	40	2807	10
BC1_28	1.95	0.0185	0.1892	0.0076	2669	40	2735	13
BC1_29	1.84	0.0231	0.1850	0.0081	2801	52	2698	13
BC1_30	1.91	0.0208	0.1852	0.0071	2713	46	2700	12
BC1_31	1.90	0.0174	0.1844	0.0060	2721	38	2693	10
BC1_32	1.66	0.0212	0.2145	0.0075	3036	51	2940	12
BC1_33	1.74	0.0246	0.1881	0.0069	2932	58	2725	11

BC1_35	1.89	0.0192	0.1868	0.0066	2739	43	2714	11
BC1_36	1.88	0.0189	0.1785	0.0076	2755	42	2639	13
BC1_39	1.80	0.0205	0.2014	0.0075	2850	47	2838	12
BC1_40	3.03	0.0172	0.1254	0.0068	1838	27	2034	12
BC1_41	1.69	0.0140	0.2104	0.0057	2997	33	2909	9
BC1_42	1.84	0.0151	0.1997	0.0069	2800	34	2824	11
BC1_43	1.76	0.0139	0.2197	0.0056	2900	32	2978	9
BC1_44	1.82	0.0132	0.1970	0.0048	2822	30	2801	8
BC1_45	1.89	0.0149	0.1963	0.0058	2735	33	2796	9
BC1_46	5.10	0.0127	0.0783	0.0068	1154	13	1155	13
BC1_47	1.86	0.0128	0.1893	0.0046	2775	29	2736	8
BC1_48	1.90	0.0145	0.1873	0.0055	2729	32	2719	9
BC1_49	1.92	0.0135	0.1844	0.0053	2705	30	2693	9
BC1_50	1.92	0.0159	0.1882	0.0059	2707	35	2727	10
BC1_51	1.83	0.0164	0.1858	0.0057	2815	37	2705	9
BC1_52	1.94	0.0160	0.1805	0.0065	2678	35	2658	11
BC1_53	2.99	0.0113	0.1125	0.0043	1860	18	1839	8
BC1_55	1.87	0.0143	0.1977	0.0056	2758	32	2807	9
BC1_56	1.98	0.0116	0.1844	0.0053	2637	25	2693	9
BC1_57	3.06	0.0116	0.1107	0.0042	1823	18	1812	8
BC1_58	1.83	0.0153	0.1848	0.0050	2808	35	2696	8
BC1_59	1.99	0.0136	0.1850	0.0047	2628	29	2698	8
BC1_60	2.85	0.0163	0.1123	0.0092	1939	27	1837	17
BC1_62	1.96	0.0225	0.1854	0.0099	2663	49	2702	16
BC1_63	1.88	0.0177	0.1889	0.0062	2746	39	2733	10
BC1_67	1.76	0.0157	0.2073	0.0062	2898	36	2885	10
BC1_70	1.83	0.0119	0.1876	0.0041	2816	27	2721	7
BC1_71	1.82	0.0145	0.1878	0.0075	2827	33	2723	12
BC1_72	1.90	0.0124	0.1859	0.0071	2729	28	2707	12
BC1_73	1.81	0.0159	0.1890	0.0204	2839	36	2734	33
BC1_74	1.87	0.0168	0.1876	0.0093	2761	38	2721	15
BC1_75	2.09	0.0141	0.1836	0.0086	2519	29	2685	14
BC1_76	1.72	0.0116	0.1841	0.0062	2953	27	2690	10
BC1_78	3.05	0.0135	0.1142	0.0080	1828	21	1868	14
BC1_79	2.01	0.0116	0.1877	0.0064	2608	25	2722	11
BC1_80	1.85	0.0103	0.1856	0.0059	2789	23	2703	10
BC1_81	3.06	0.0135	0.1125	0.0088	1824	21	1840	16
BC1_83	1.93	0.0144	0.1863	0.0070	2686	32	2709	12
BC1_84	1.96	0.0132	0.1849	0.0068	2663	29	2697	11
BC1_85	1.91	0.0130	0.1855	0.0068	2712	29	2702	11

BC1_86	1.94	0.0166	0.1867	0.0072	2675	36	2713	12
BC1_88	3.11	0.0152	0.1089	0.0074	1800	24	1782	13
BC1_89	1.70	0.0160	0.2157	0.0071	2989	38	2949	11
BC1_90	1.78	0.0215	0.1976	0.0087	2880	50	2807	14
BC1_91	2.90	0.0136	0.1137	0.0064	1908	22	1860	11
BC1_92	1.44	0.0139	0.3020	0.0060	3397	37	3480	9
BC1_93	1.89	0.0127	0.1841	0.0056	2737	28	2690	9
BC1_94	1.90	0.0148	0.1853	0.0067	2729	33	2701	11
BC1_95	2.98	0.0132	0.1147	0.0059	1868	21	1876	11
BC1_96	1.83	0.0134	0.1889	0.0060	2807	30	2733	10
BC1_97	1.83	0.0173	0.1873	0.0076	2811	39	2718	12
BC1_98	1.76	0.0161	0.1874	0.0064	2901	38	2719	11
BC1_99	1.98	0.0232	0.1839	0.0072	2635	50	2689	12
BC1_100	1.68	0.0180	0.2192	0.0073	3008	43	2975	12
BC1_101	1.86	0.0146	0.1998	0.0585	2769	33	2825	92
BC1_102	1.97	0.0140	0.1850	0.0058	2643	30	2698	9
BC1_103	1.92	0.0101	0.1853	0.0048	2701	22	2701	8
BC1_104	3.08	0.0091	0.1117	0.0049	1812	14	1827	9
BC1_105	1.83	0.0112	0.2015	0.0047	2807	25	2839	8
BC1_106	1.92	0.0121	0.1899	0.0045	2702	27	2741	7
BC1_107	3.03	0.0086	0.1147	0.0040	1837	14	1876	7
BC1_108	1.92	0.0119	0.1850	0.0057	2703	26	2698	9
BC1_110	1.97	0.0138	0.1889	0.0064	2648	30	2732	11
BC1_111	3.14	0.0085	0.1143	0.0048	1784	13	1868	9
BC1_112	1.89	0.0135	0.1860	0.0060	2742	30	2707	10
BC1_113	2.02	0.0143	0.1880	0.0065	2591	30	2724	11
BC1_114	1.93	0.0145	0.1936	0.0062	2686	32	2773	10
BC1_115	1.87	0.0121	0.1865	0.0048	2766	27	2712	8
BC1_116	1.90	0.0207	0.1877	0.0065	2731	46	2722	11
BC1_117	2.00	0.0205	0.1893	0.0055	2616	44	2736	9
BC1_118	1.90	0.0194	0.2035	0.0062	2721	43	2855	10
BC1_120	1.95	0.0182	0.1846	0.0045	2668	40	2695	7
BC1_121	1.96	0.0204	0.1874	0.0069	2657	44	2719	11
BC1_122	1.92	0.0204	0.1855	0.0068	2708	45	2703	11
BC1_123	1.97	0.0190	0.1819	0.0049	2651	41	2670	8
BC1_124	2.03	0.0186	0.1838	0.0046	2583	39	2688	8
BC1_125	3.17	0.0180	0.1099	0.0053	1768	28	1798	10
BC1_126	2.00	0.0234	0.1879	0.0076	2613	50	2723	12
BC1_127	1.94	0.0204	0.2016	0.0059	2684	45	2839	10
BC1_128	1.87	0.0225	0.2015	0.0078	2765	50	2838	13

BC1_129	1.83	0.0193	0.2015	0.0055	2816	44	2839	9
BC1_130	1.85	0.0191	0.2001	0.0051	2784	43	2827	8
			>10% Discordant					
BC1_37	4.93	0.0273	0.1132	0.0114	1191	30	1851	20
BC1_38	2.32	0.0253	0.1836	0.0068	2312	49	2686	11
BC1_54	2.47	0.0139	0.1834	0.0051	2189	26	2684	8
BC1_64	2.33	0.0199	0.1797	0.0075	2305	39	2650	12
BC1_65	2.36	0.0125	0.1845	0.0034	2273	24	2694	6
BC1_66	2.26	0.0175	0.1846	0.0034	2364	34	2695	6
BC1_68	2.77	0.0158	0.1826	0.0047	1986	27	2676	8
BC1_69	2.62	0.0175	0.1813	0.0045	2082	31	2665	7
BC1_77	2.33	0.0159	0.1887	0.0070	2304	31	2731	11
BC1_82	2.53	0.0116	0.1584	0.0081	2147	21	2439	14
BC1_87	2.20	0.0158	0.1838	0.0063	2416	32	2687	10
BC1_109	3.51	0.0211	0.1158	0.0091	1616	30	1892	16
BC1_119	3.93	0.0214	0.1841	0.0047	1463	28	2690	8

C-2 Bear Lake Lower Middle

Sample	**$^{238}U/^{206}PB$**	**1σ (%)**	**$^{207}Pb/^{206}PB$**	**1σ (%)**	**$^{238}U/^{206}PB$ Age (Ma)**	**1σ**	**$^{207}Pb/^{206}PB$ Age (Ma)**	**1σ**
			Bear Lake (Lower Medial) <10% Discordant					
BL4_6a	2.01	0.0176	0.1995	0.0125	2605	38	2822	20
BL4_10a	1.95	0.0166	0.2065	0.0125	2664	36	2878	20
BL4_16a	3.19	0.0158	0.1178	0.0135	1759	24	1924	24
BL4_17a	3.03	0.0144	0.1254	0.0123	1841	23	2035	22
BL4_20a	3.37	0.0148	0.1131	0.0126	1675	22	1851	23
BL4_31a	1.98	0.0165	0.1964	0.0124	2639	36	2796	20
BL4_44a	2.12	0.0161	0.1865	0.0128	2491	33	2711	21
BL4_46a	3.33	0.0138	0.1129	0.0121	1693	21	1847	22
BL4_64a	2.12	0.0149	0.1755	0.0124	2491	31	2611	21
BL4_80a	2.90	0.0159	0.1223	0.0113	1912	26	1990	20
BL4_84a	3.14	0.0178	0.1124	0.0115	1784	28	1839	21
BL4_93a	1.75	0.0242	0.2201	0.0125	2910	56	2982	20
BL4_107a	2.55	0.0259	0.1288	0.0130	2133	47	2081	23
BL4_114a	1.95	0.0227	0.1876	0.0116	2666	49	2721	19
BL4_118a	2.01	0.0232	0.1898	0.0123	2606	50	2741	20
BL4_126a	2.99	0.0197	0.1156	0.0122	1860	32	1890	22
BL4_127a	1.98	0.0239	0.1868	0.0128	2638	52	2714	21
BL4_132a	1.81	0.0188	0.2160	0.0113	2836	43	2951	18
BL4_133a	1.88	0.0170	0.1887	0.0115	2754	38	2730	19
BL4_135a	1.83	0.0247	0.1877	0.0129	2805	56	2722	21
BL4_142a	2.27	0.0247	0.1418	0.0132	2353	48	2250	23
BL4_143a	3.15	0.0160	0.1157	0.0074	1779	25	1891	13
BL4_144a	1.90	0.0220	0.1856	0.0117	2728	49	2704	19
BL4_147a	2.90	0.0229	0.1306	0.0111	1908	38	2106	19
BL4_150a	2.01	0.0202	0.1866	0.0125	2603	43	2712	20
BL4_154a	1.99	0.0151	0.1902	0.0073	2628	33	2744	12
BL4_155a	1.78	0.0259	0.1891	0.0127	2880	60	2734	21
BL4_156a	2.06	0.0158	0.1909	0.0073	2555	33	2750	12
BL4_165a	1.85	0.0251	0.1875	0.0124	2789	57	2721	20
BL4_179a	1.95	0.0208	0.1822	0.0137	2670	45	2673	23
BL4_181a	2.04	0.0165	0.1889	0.0073	2573	35	2733	12
BL4_182a	1.71	0.0207	0.2171	0.0113	2962	49	2959	18
BL4_213a	3.21	0.0177	0.1142	0.0089	1747	27	1867	16
BL4_224a	1.90	0.0232	0.1848	0.0126	2724	51	2696	21
BL4_227a	2.01	0.0228	0.1740	0.0125	2602	49	2597	21

BL4_230a	3.04	0.0165	0.1142	0.0124	1832	26	1867	22
BL4_235a	3.11	0.0211	0.1182	0.0124	1795	33	1930	22
BL4_238a	1.84	0.0232	0.1909	0.0123	2800	52	2750	20
BL4_255	1.47	0.0153	0.3154	0.0067	3341	40	3547	10
BL4_258a	2.08	0.0160	0.1706	0.0114	2532	33	2564	19
BL4_262a	1.89	0.0268	0.1857	0.0130	2738	59	2704	21
BL4_277	3.09	0.0159	0.1187	0.0080	1807	25	1937	14
BL4_283a	1.88	0.0245	0.1856	0.0129	2747	55	2703	21
BL4_287a	1.87	0.0272	0.1874	0.0131	2759	61	2720	21
BL4_290a	2.55	0.0247	0.1355	0.0152	2136	45	2170	26
BL4_293a	1.97	0.0153	0.1845	0.0118	2645	33	2694	19
BL4_295a	1.85	0.0115	0.2036	0.0088	2789	26	2855	14
BL4_303a	1.93	0.0159	0.1904	0.0093	2688	35	2746	15
BL4_304a	3.14	0.0182	0.1138	0.0113	1781	28	1861	20
BL4_310a	1.96	0.0204	0.1907	0.0093	2659	44	2749	15
BL4_314a	2.40	0.0110	0.1493	0.0088	2244	21	2338	15
BL4_315a	2.67	0.0240	0.1433	0.0664	2051	42	2267	110
BL4_321a	1.89	0.0136	0.1872	0.0095	2739	30	2718	16
BL4_325a	1.86	0.0125	0.1891	0.0083	2775	28	2735	14
BL4_326a	1.86	0.0194	0.1915	0.0084	2768	43	2755	14
BL4_330a	1.89	0.0245	0.1905	0.0127	2740	54	2747	21
BL4_332a_bottom	2.70	0.0278	0.1273	0.0135	2034	48	2061	24
BL4_334a	2.05	0.0184	0.1817	0.0089	2566	39	2668	15
BL4_335a	1.79	0.0192	0.2246	0.0093	2859	44	3014	15
BL4_347a	1.98	0.0167	0.1956	0.0076	2634	36	2790	12
BL4_360a	1.98	0.0228	0.1874	0.0061	2640	49	2720	10
BL4_362a	1.87	0.0190	0.1895	0.0083	2760	43	2737	14
BL4_364a	1.92	0.0156	0.1850	0.0085	2705	34	2698	14
BL4_379a	1.78	0.0292	0.1855	0.0113	2875	67	2703	18
BL4_380a	2.08	0.0253	0.1894	0.0139	2528	53	2737	23
BL4_384a	2.01	0.0281	0.1806	0.0130	2600	60	2659	21
BL4_399a	1.70	0.0288	0.2315	0.0080	2984	68	3063	13
BL4_402a	1.97	0.0183	0.2025	0.0081	2651	40	2846	13
BL4_412a	2.95	0.0182	0.1134	0.0095	1884	30	1855	17
BL4_428a	2.10	0.0206	0.1828	0.0058	2508	43	2679	10
BL4_429a	1.87	0.0250	0.1863	0.0108	2764	56	2710	18
BL4_435a	2.10	0.0249	0.1882	0.0151	2512	52	2726	25
BL4_438a	2.30	0.0282	0.1615	0.0057	2323	55	2471	10
BL4_441a	2.76	0.0212	0.1343	0.0093	1991	36	2155	16
BL4_463a	3.12	0.0215	0.1123	0.0085	1790	33	1837	15

BL4_467a	2.02	0.0210	0.1880	0.0059	2597	45	2724	10
BL4_469a	2.04	0.0229	0.1846	0.0062	2566	48	2695	10
BL4_494a	3.13	0.0217	0.1144	0.0064	1788	34	1870	12
BL4_499a	2.06	0.0227	0.1866	0.0066	2546	48	2712	11
BL4_517a	2.98	0.0265	0.1135	0.0083	1865	43	1856	15
BL4_524a	1.80	0.0281	0.1874	0.0064	2844	64	2720	11
			>10% Discordant					
BL4_72a	2.78	0.0467	0.2015	0.0129	1980	79	2839	21
BL4_85a_top	2.49	0.0156	0.1615	0.0112	2173	29	2471	19
BL4_103a	2.14	0.0169	0.1932	0.0110	2474	35	2769	18
BL4_115a	2.29	0.0180	0.1969	0.0110	2337	35	2800	18
BL4_145a	2.10	0.0157	0.3092	0.0124	2510	33	3517	19
BL4_170a	1.82	0.0182	0.2474	0.0074	2824	41	3168	12
BL4_196a	4.33	0.1148	0.1332	0.0193	1341	137	2141	33
BL4_208a	2.99	0.0301	0.1788	0.0349	1861	49	2642	57
BL4_217a	5.93	0.0108	0.1808	0.0109	1004	10	2660	18
BL4_228	2.44	0.0167	0.2380	0.0072	2214	31	3106	11
BL4_265a	2.62	0.0692	0.2110	0.0163	2085	122	2914	26
BL4_323a	2.16	0.0401	0.2338	0.0121	2454	81	3078	19
BL4_356a	3.06	0.0269	0.1913	0.0055	1821	43	2754	9
BL4_359a	2.03	0.0531	0.2248	0.0134	2578	112	3015	21
BL4_388a	7.53	0.0208	0.1119	0.0059	803	16	1830	11
BL4_405a	5.21	0.0232	0.1861	0.0056	1132	24	2708	9
BL4_424a	3.05	0.0190	0.1359	0.0053	1828	30	2176	9
BL4_460a	2.85	0.0304	0.2075	0.0272	1938	51	2886	43
BL4_482a	2.16	0.0256	0.1894	0.0060	2448	52	2737	10
BL4_488a	2.35	0.0247	0.1953	0.0050	2284	47	2788	8

C-3 Bear Lake Upper Medial

Sample	$^{238}U/^{206}PB$	1σ (%)	$^{207}Pb/^{206}PB$	1σ (%)	$^{238}U/^{206}PB$ Age (Ma)	1σ	$^{207}Pb/^{206}PB$ Age (Ma)	1σ
			Bear Lake (Upper Medial) <10% Discordant					
BL6_27a	3.18	0.0196	0.1121	0.0127	1762	30	1834	23
BL6_93a	2.02	0.0159	0.1812	0.0102	2594	34	2664	17
BL6_133a	3.21	0.0172	0.1133	0.0127	1750	26	1852	23
BL6_201a	2.98	0.0276	0.1169	0.0092	1863	45	1909	16
BL6_207a	1.90	0.0183	0.1866	0.0087	2728	41	2712	14
BL6_238a	3.21	0.0210	0.1120	0.0126	1746	32	1833	23
BL6_246a	3.06	0.0453	0.1119	0.0100	1821	72	1831	18
BL6_252a	3.14	0.0118	0.1128	0.0091	1783	18	1846	16
BL6_257a	3.01	0.0450	0.1122	0.0087	1851	72	1835	16
BL6_263a	2.95	0.0390	0.1124	0.0089	1881	63	1838	16
BL6_266a	1.91	0.0295	0.1833	0.0076	2714	65	2683	13
BL6_268a	2.85	0.0268	0.1161	0.0067	1937	45	1897	12
BL6_273a	2.84	0.0431	0.1172	0.0090	1944	72	1915	16
BL6_277a	2.90	0.0417	0.1167	0.0130	1910	69	1906	23
BL6_279a	1.84	0.0159	0.1826	0.0067	2802	36	2677	11
BL6_282a	2.03	0.0283	0.1819	0.0081	2577	60	2671	13
BL6_283a	1.74	0.0224	0.2151	0.0079	2926	52	2944	13
BL6_285a	2.76	0.0458	0.1269	0.0118	1991	78	2055	21
BL6_286a	3.01	0.0153	0.1140	0.0064	1849	25	1864	12
BL6_295a	3.06	0.0290	0.1114	0.0100	1823	46	1823	18
BL6_299a	1.94	0.0455	0.1857	0.0083	2681	99	2704	14
BL6_305a	2.68	0.0165	0.1387	0.0157	2042	29	2211	27
BL6_309a	3.06	0.0127	0.1153	0.0076	1822	20	1885	14
BL6_315a	2.88	0.0412	0.1276	0.0075	1920	68	2065	13
BL6_324a	1.84	0.0194	0.2057	0.0073	2792	44	2872	12
BL6_325a	3.03	0.0418	0.1137	0.0101	1839	67	1859	18
BL6_330a	3.17	0.0146	0.1147	0.0093	1767	23	1874	17
BL6_331a	3.00	0.0387	0.1131	0.0088	1853	62	1850	16
BL6_345a	1.91	0.0408	0.1884	0.0066	2709	90	2728	11
BL6_347a	1.91	0.0189	0.1840	0.0065	2712	42	2689	11
BL6_348a	3.06	0.0289	0.1145	0.0068	1822	46	1872	12
BL6_351a	5.83	0.0143	0.0758	0.0103	1020	13	1090	20
BL6_352a	2.89	0.0399	0.1181	0.0073	1915	66	1927	13
BL6_353a	3.07	0.0127	0.1118	0.0070	1816	20	1828	13
BL6_354a	1.90	0.0216	0.1863	0.0076	2721	48	2710	13

BL6_357a	2.28	0.0360	0.1443	0.0073	2342	70	2280	12
BL6_359a	3.11	0.0131	0.1157	0.0181	1797	20	1891	32
BL6_361a	3.05	0.0209	0.1132	0.0120	1829	33	1851	21
BL6_365a	3.18	0.0190	0.1118	0.0105	1761	29	1829	19
BL6_368a	3.03	0.0302	0.1155	0.0071	1840	48	1888	13
BL6_370a	2.88	0.0438	0.1140	0.0075	1923	72	1864	14
BL6_377a	1.92	0.0127	0.1876	0.0059	2703	28	2721	10
BL6_383a	2.82	0.0461	0.1163	0.0101	1957	77	1900	18
BL6_384a	2.13	0.0138	0.1687	0.0066	2479	28	2545	11
BL6_398a	3.11	0.0153	0.1109	0.0069	1797	24	1815	12
BL6_400a	3.00	0.0486	0.1145	0.0096	1855	78	1872	17
BL6_401a	2.89	0.0178	0.1177	0.0087	1915	29	1922	15
BL6_404a	2.14	0.0176	0.1789	0.0097	2470	36	2642	16
BL6_406a	1.90	0.0277	0.1922	0.0124	2726	61	2761	20
BL6_409a	1.88	0.0473	0.1816	0.0083	2751	105	2668	14
BL6_421a	3.04	0.0170	0.1131	0.0111	1836	27	1850	20
BL6_424a	1.73	0.0418	0.2057	0.0071	2944	98	2872	11
BL6_427a	3.02	0.0374	0.1117	0.0093	1843	60	1827	17
BL6_450a	1.85	0.0198	0.1923	0.0097	2780	45	2762	16
BL6_463a	3.00	0.0401	0.1123	0.0109	1855	64	1838	20
BL6_477a_left	2.14	0.0203	0.1689	0.0099	2472	42	2547	17
BL6_488a	2.02	0.0183	0.1875	0.0098	2589	39	2720	16
BL6_490a	1.73	0.0240	0.1989	0.0125	2938	56	2817	20
BL6_491a	3.10	0.0208	0.1126	0.0125	1802	33	1841	22
BL6_501a	2.83	0.0159	0.1174	0.0097	1953	27	1918	17
BL6_516a	3.08	0.0231	0.1110	0.0130	1814	36	1815	23
BL6_519a	2.03	0.0147	0.1829	0.0091	2587	31	2679	15
BL6_520a	3.01	0.0239	0.1180	0.0116	1847	38	1926	21
BL6_522a	2.64	0.0213	0.1293	0.0124	2073	38	2089	22
BL6_534a	3.12	0.0221	0.1184	0.0109	1793	34	1932	19
BL6_535a	2.80	0.0209	0.1187	0.0119	1971	35	1936	21
BL6_550a	2.94	0.0164	0.1147	0.0097	1885	27	1875	17
BL6_552a	1.94	0.0186	0.1898	0.0106	2680	41	2741	17
BL6_559a	1.99	0.0167	0.1821	0.0089	2627	36	2672	15
BL6_563a	3.02	0.0187	0.1135	0.0104	1844	30	1856	19
BL6_573a	2.99	0.0175	0.1178	0.0104	1859	28	1923	19
BL6_577a	2.93	0.0218	0.1173	0.0123	1894	36	1915	22
BL6_597a	1.85	0.0268	0.1971	0.0110	2788	60	2803	18
BL6_598a	3.04	0.0190	0.1130	0.0106	1836	30	1848	19
BL6_601a	2.62	0.0262	0.1229	0.0130	2086	47	1998	23

BL6_619a	1.66	0.0327	0.2063	0.0138	3046	79	2877	22
BL6_621a	1.94	0.0213	0.1850	0.0099	2680	47	2698	16
BL6_625a	1.55	0.0348	0.2211	0.0187	3206	87	2989	30
BL6_626a	2.98	0.0179	0.1131	0.0103	1867	29	1850	18
BL6_629a	1.91	0.0267	0.1930	0.0191	2716	59	2768	31
BL6_636a	1.82	0.0218	0.1885	0.0102	2824	50	2729	17
BL6_669a	2.96	0.0213	0.1140	0.0105	1877	35	1863	19
BL6_675a	3.17	0.0178	0.1112	0.0103	1766	27	1820	18
BL6_698a	1.92	0.0185	0.1848	0.0098	2702	41	2697	16
BL6_706a	1.58	0.0202	0.2264	0.0136	3158	50	3026	22
BL6_707a	2.10	0.0245	0.1656	0.0105	2513	51	2513	18
BL6_709a	2.85	0.0372	0.1138	0.0194	1938	62	1860	35
BL6_711a	1.92	0.0255	0.1844	0.0110	2706	56	2693	18
BL6_718a	3.23	0.0202	0.1095	0.0124	1737	31	1791	22
BL6_730a	2.66	0.0258	0.1382	0.0200	2056	45	2205	34
BL6_731a	3.02	0.0224	0.1117	0.0118	1842	36	1828	21
BL6_753a	1.88	0.0203	0.1905	0.0104	2745	45	2746	17
			>10% Discordant					
BL6_38a	16.14	0.0159	0.3262	0.0089	388	6	3599	14
BL6_122a	4.50	0.0151	0.1293	0.0093	1295	18	2088	16
BL6_218a	3.38	0.0265	0.1144	0.0081	1669	39	1870	14
BL6_243a	3.20	0.0406	0.1204	0.0114	1754	62	1962	20
BL6_259a	14.68	0.0700	0.2497	0.0073	425	29	3183	11
BL6_303a	1.96	0.0425	0.2607	0.0190	2655	92	3251	30
BL6_329a	2.45	0.0273	0.2479	0.0060	2204	51	3171	9
BL6_360a	2.90	0.0261	0.1467	0.0059	1908	43	2308	10
BL6_413a	4.32	0.0404	0.2278	0.0096	1341	49	3037	15
BL6_428a	2.33	0.0633	0.2452	0.0328	2304	122	3154	51
BL6_438a	2.90	0.0389	0.1931	0.0059	1911	64	2769	10
BL6_477a_right	3.02	0.0217	0.1459	0.0149	1844	35	2299	25
BL6_526a	3.52	0.0175	0.1130	0.0101	1612	25	1848	18
BL6_656a	8.90	0.0111	0.4079	0.0089	686	7	3939	13
BL6_694a	3.01	0.0302	0.1926	0.0098	1847	48	2765	16
BL6_703a	2.30	0.0380	0.1940	0.0218	2325	74	2777	35
BL6_739a	3.13	0.0221	0.1243	0.1057	1785	34	2018	176

C-4 Bear Lake Top

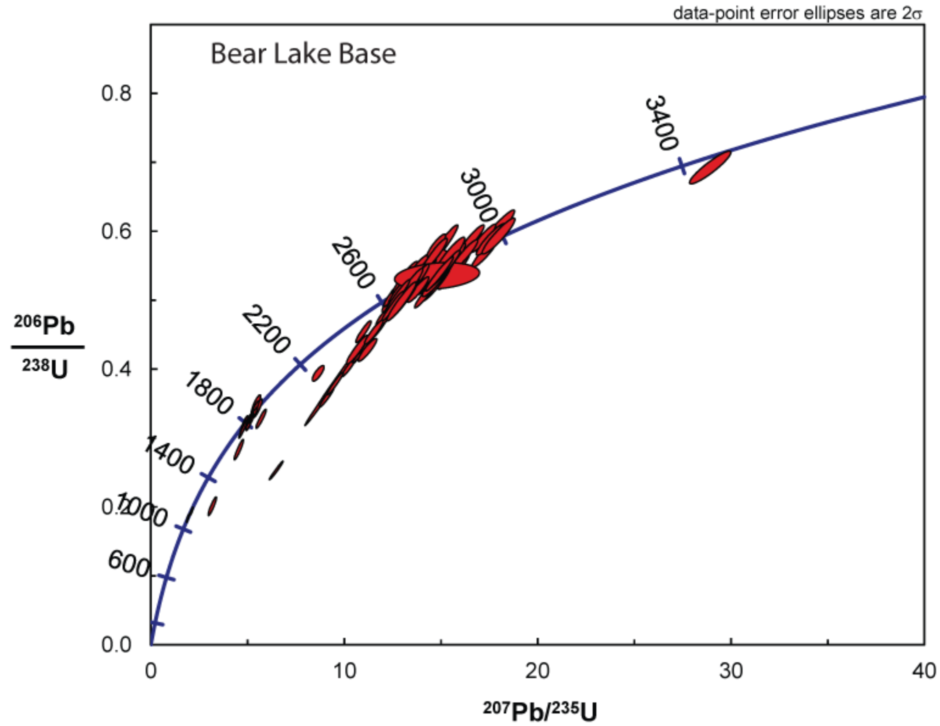
Sample	**$^{238}U/^{206}PB$**	**1σ (%)**	**$^{207}Pb/^{206}PB$**	**1σ (%)**	**$^{238}U/^{206}PB$ Age (Ma)**	**1σ**	**$^{207}Pb/^{206}PB$ Age (Ma)**	**1σ**
			Bear Lake (Top) <10% Discordant					
BC4_1	3.30	0.0253	0.1132	0.0056	1708	38	1851	10
BC4_2	2.98	0.0251	0.1178	0.0054	1865	40	1923	10
BC4_3	3.18	0.0255	0.1174	0.0048	1764	39	1917	9
BC4_4	3.06	0.0250	0.1167	0.0046	1823	40	1907	8
BC4_5	3.41	0.0252	0.1112	0.0048	1659	37	1819	9
BC4_6	3.11	0.0275	0.1172	0.0084	1800	43	1915	15
BC4_7	3.17	0.0253	0.1120	0.0058	1767	39	1831	10
BC4_8	2.23	0.0249	0.1666	0.0048	2385	49	2524	8
BC4_10	2.02	0.0253	0.1858	0.0053	2590	54	2705	9
BC4_11	3.08	0.0155	0.1141	0.0057	1812	24	1866	10
BC4_12	1.95	0.0157	0.1826	0.0057	2668	34	2677	9
BC4_14	2.06	0.0184	0.1886	0.0067	2550	39	2730	11
BC4_16	3.11	0.0153	0.1135	0.0054	1798	24	1857	10
BC4_17	2.99	0.0154	0.1172	0.0057	1859	25	1913	10
BC4_19	3.17	0.0155	0.1132	0.0056	1770	24	1851	10
BC4_21	2.06	0.0172	0.1857	0.0070	2549	36	2704	11
BC4_22	3.10	0.0154	0.1146	0.0056	1802	24	1874	10
BC4_24	3.06	0.0164	0.1159	0.0070	1821	26	1894	12
BC4_25	3.27	0.0154	0.1129	0.0058	1718	23	1847	10
BC4_26	3.36	0.0171	0.1131	0.0059	1679	25	1849	11
BC4_28	2.69	0.0169	0.1313	0.0059	2037	30	2116	13
BC4_29	3.18	0.0178	0.1127	0.0072	1762	27	1844	14
BC4_30	1.93	0.0170	0.1852	0.0057	2694	37	2700	15
BC4_31	2.76	0.0174	0.1294	0.0062	1993	30	2089	16
BC4_32	3.25	0.0178	0.1162	0.0070	1729	27	1898	17
BC4_33	3.28	0.0172	0.1114	0.0059	1713	26	1822	18
BC4_34	3.16	0.0173	0.1123	0.0065	1773	27	1836	19
BC4_35	2.42	0.0169	0.1501	0.0057	2229	32	2347	20
BC4_36	2.19	0.0172	0.1661	0.0055	2428	35	2519	21
BC4_37	1.96	0.0173	0.1938	0.0058	2656	37	2775	22
BC4_38	2.08	0.0169	0.1822	0.0058	2526	35	2673	23
BC4_39	3.27	0.0172	0.1128	0.0062	1719	26	1845	24
BC4_40	1.97	0.0208	0.1904	0.0079	2645	45	2746	25
BC4_41	3.10	0.0120	0.1126	0.0071	1801	19	1842	13
BC4_42	3.12	0.0100	0.1121	0.0037	1795	16	1833	7

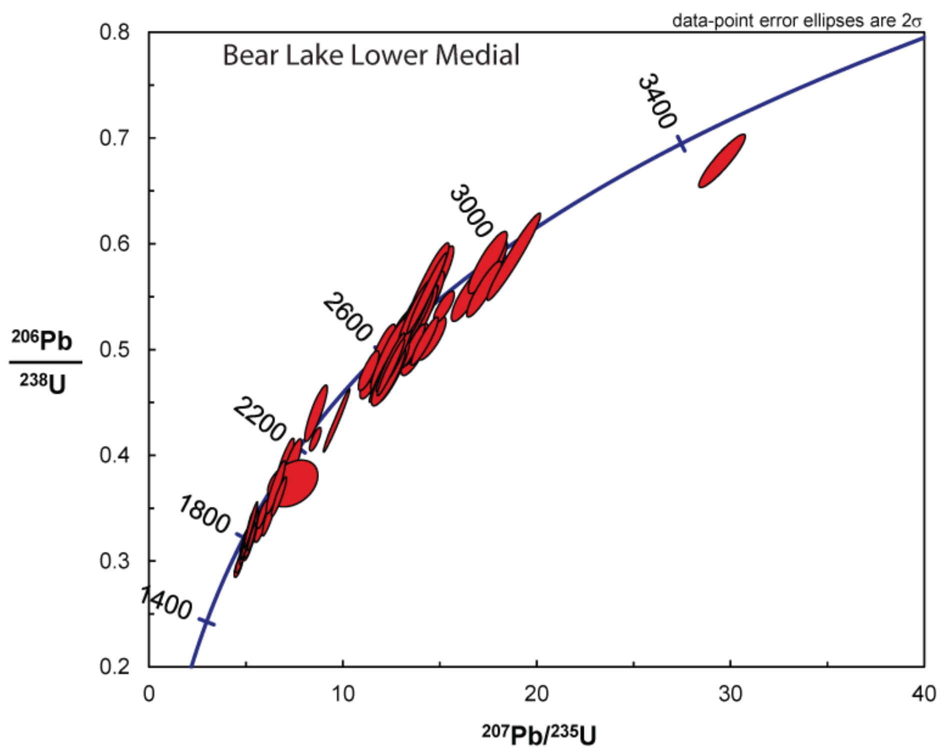
BC4_43	3.16	0.0119	0.1110	0.0060	1770	18	1816	11
BC4_45	2.98	0.0116	0.1183	0.0057	1867	19	1931	10
BC4_46	3.11	0.0103	0.1133	0.0044	1799	16	1853	8
BC4_48	3.08	0.0106	0.1136	0.0055	1811	17	1857	10
BC4_49	1.99	0.0113	0.1855	0.0044	2627	24	2702	7
BC4_50	3.10	0.0122	0.1131	0.0065	1802	19	1849	12
BC4_51	2.78	0.0104	0.1303	0.0039	1980	18	2102	7
BC4_52	3.03	0.0120	0.1156	0.0060	1836	19	1890	11
BC4_53	3.12	0.0119	0.1121	0.0058	1794	19	1834	10
BC4_54	3.15	0.0103	0.1131	0.0041	1776	16	1849	7
BC4_55	1.91	0.0103	0.1891	0.0038	2720	23	2734	6
BC4_56	3.01	0.0158	0.1160	0.0064	1851	25	1895	11
BC4_57	3.19	0.0152	0.1092	0.0053	1756	23	1786	10
BC4_58	3.13	0.0153	0.1124	0.0059	1785	24	1839	11
BC4_59	2.91	0.0150	0.1195	0.0054	1905	25	1948	10
BC4_60	1.99	0.0152	0.1827	0.0049	2626	33	2678	8
BC4_61	2.66	0.0158	0.1294	0.0063	2057	28	2090	11
BC4_62	3.20	0.0151	0.1122	0.0058	1751	23	1835	10
BC4_64	2.72	0.0156	0.1282	0.0063	2018	27	2073	11
BC4_65	2.07	0.0154	0.1866	0.0049	2543	32	2712	8
BC4_66	1.96	0.0149	0.1846	0.0053	2658	32	2695	9
BC4_68	2.78	0.0153	0.1329	0.0060	1980	26	2136	10
BC4_69	2.16	0.0157	0.1679	0.0056	2453	32	2537	9
BC4_70	1.90	0.0155	0.1858	0.0054	2722	34	2705	9
BC4_71	2.89	0.0194	0.1199	0.0053	1916	32	1955	9
BC4_72	3.14	0.0189	0.1120	0.0046	1784	29	1832	8
BC4_73	3.13	0.0190	0.1147	0.0048	1785	29	1875	9
BC4_74	1.86	0.0189	0.2287	0.0047	2777	43	3043	8
BC4_75	3.24	0.0203	0.1109	0.0074	1736	31	1814	13
BC4_77	3.17	0.0192	0.1122	0.0052	1766	30	1835	9
BC4_78	3.18	0.0190	0.1126	0.0053	1764	29	1842	10
BC4_79	3.05	0.0193	0.1205	0.0064	1827	31	1963	11
BC4_80	3.21	0.0202	0.1130	0.0071	1747	31	1848	13
BC4_81	2.80	0.0191	0.1349	0.0058	1968	32	2163	10
BC4_82	1.90	0.0203	0.2035	0.0059	2722	45	2854	10
BC4_83	3.39	0.0203	0.1126	0.0063	1665	30	1841	11
BC4_84	3.01	0.0190	0.1187	0.0048	1851	31	1937	9
BC4_85	2.03	0.0220	0.1878	0.0078	2579	47	2723	13
BC4_100	2.95	0.0137	0.1173	0.0039	1880	22	1916	7
BC4_86	2.89	0.0139	0.1227	0.0038	1918	23	1996	7

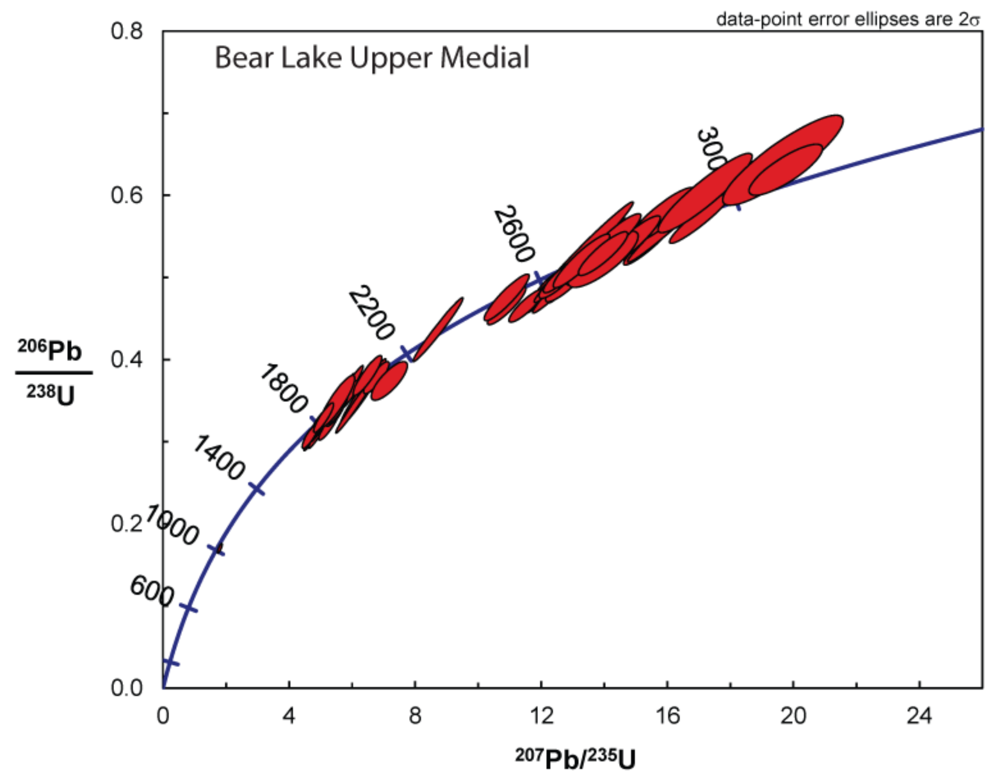
BC4_87	2.15	0.0139	0.1701	0.0037	2466	28	2558	6
BC4_89	3.11	0.0141	0.1167	0.0042	1796	22	1907	8
BC4_90	3.03	0.0149	0.1150	0.0057	1840	24	1880	10
BC4_91	3.15	0.0138	0.1112	0.0036	1775	21	1819	7
BC4_93	2.75	0.0181	0.1274	0.0076	2000	31	2062	13
BC4_95	3.17	0.0140	0.1135	0.0040	1769	22	1856	7
BC4_97	3.24	0.0140	0.1087	0.0040	1735	21	1779	7
BC4_98	3.18	0.0140	0.1131	0.0042	1764	22	1849	8
BC4_99	2.72	0.0139	0.1295	0.0044	2020	24	2091	8
BC4_101	2.92	0.0256	0.1145	0.0054	1899	42	1873	10
BC4_102	3.23	0.0264	0.1117	0.0063	1741	40	1827	11
BC4_103	3.01	0.0260	0.1155	0.0064	1851	42	1888	12
BC4_104	2.86	0.0266	0.1120	0.0060	1934	44	1832	11
BC4_105	1.87	0.0255	0.1920	0.0053	2758	57	2759	9
BC4_108	1.92	0.0258	0.1863	0.0056	2704	57	2710	9
BC4_109	2.69	0.0259	0.1165	0.0063	2035	45	1903	11
BC4_110	2.99	0.0262	0.1162	0.0069	1862	42	1898	12
BC4_111	3.12	0.0260	0.1122	0.0071	1794	41	1836	13
BC4_112	3.08	0.0255	0.1127	0.0055	1812	40	1844	10
BC4_113	2.70	0.0265	0.1303	0.0066	2031	46	2102	12
BC4_114	2.87	0.0253	0.1170	0.0054	1926	42	1911	10
BC4_115	1.96	0.0258	0.1911	0.0051	2654	56	2752	8
BC4_116	3.11	0.0226	0.1080	0.0050	1797	35	1766	9
BC4_117	2.18	0.0296	0.1816	0.0054	2437	60	2667	9
BC4_120	3.04	0.0224	0.1127	0.0052	1834	36	1844	9
BC4_121	2.98	0.0227	0.1121	0.0049	1863	37	1834	9
BC4_122	2.29	0.0227	0.1435	0.0052	2332	44	2270	9
BC4_123	2.57	0.0228	0.1374	0.0058	2117	41	2194	10
BC4_124	3.01	0.0234	0.1145	0.0066	1851	38	1872	12
BC4_125	2.60	0.0227	0.1276	0.0051	2097	41	2065	9
BC4_126	2.98	0.0225	0.1138	0.0051	1864	36	1862	9
BC4_127	1.86	0.0226	0.1865	0.0050	2770	51	2711	8
BC4_128	4.12	0.0229	0.0884	0.0064	1401	29	1391	12
BC4_129	2.17	0.0233	0.1760	0.0055	2441	47	2615	9
BC4_130	3.18	0.0224	0.1092	0.0052	1763	34	1785	9
			>10% Discordant					
BC4_9	9.82	0.1527	0.3364	0.0370	625	90	3646	56
BC4_13	3.71	0.0160	0.1065	0.0065	1538	22	1740	12
BC4_15	3.44	0.0163	0.1162	0.0066	1646	24	1899	12
BC4_18	2.58	0.0155	0.1867	0.0058	2113	28	2713	10

BC4_20	3.45	0.0190	0.1319	0.0072	1640	27	2123	13
BC4_27	4.70	0.0248	0.1306	0.0078	1244	28	2107	12
BC4_44	2.89	0.0106	0.1386	0.0039	1915	18	2209	7
BC4_47	6.21	0.0143	0.2289	0.0098	962	13	3044	16
BC4_63	3.12	0.0164	0.1343	0.0067	1792	26	2155	12
BC4_67	4.53	0.0191	0.1312	0.0082	1287	22	2114	14
BC4_76	2.24	0.0192	0.1869	0.0048	2377	38	2715	8
BC4_88	3.24	0.0143	0.1296	0.0071	1736	22	2093	13
BC4_94	6.04	0.0336	0.1644	0.0242	988	31	2501	40
BC4_106	2.36	0.0268	0.1770	0.0206	2275	51	2625	34
BC4_118	3.19	0.0227	0.1417	0.0084	1757	35	2248	14
BC4_119	2.56	0.0232	0.1519	0.0083	2129	42	2368	14

WETHERILL PLOTS



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Bear Lake Upper Medial
206Pb/238U
207Pb/235U
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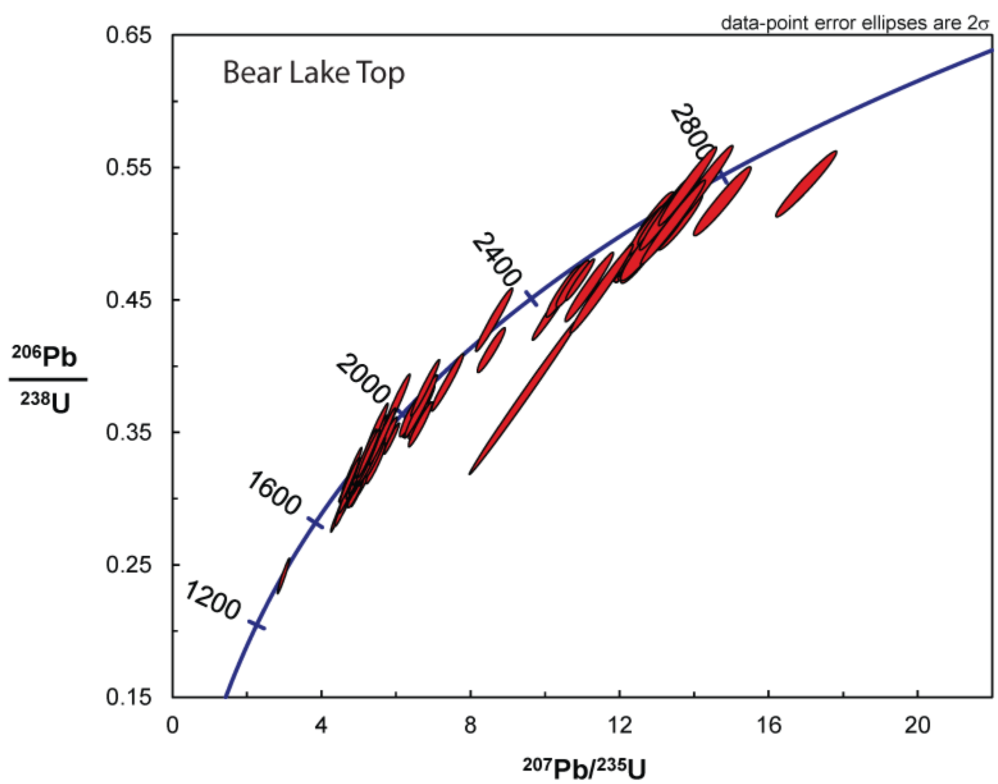
0.6
0.4
0.2
0.0
0
4
8
12
16
20
24
600
1000
1400
1800
2200
2600
300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Bear Lake Top
206Pb/238U
207Pb/235U
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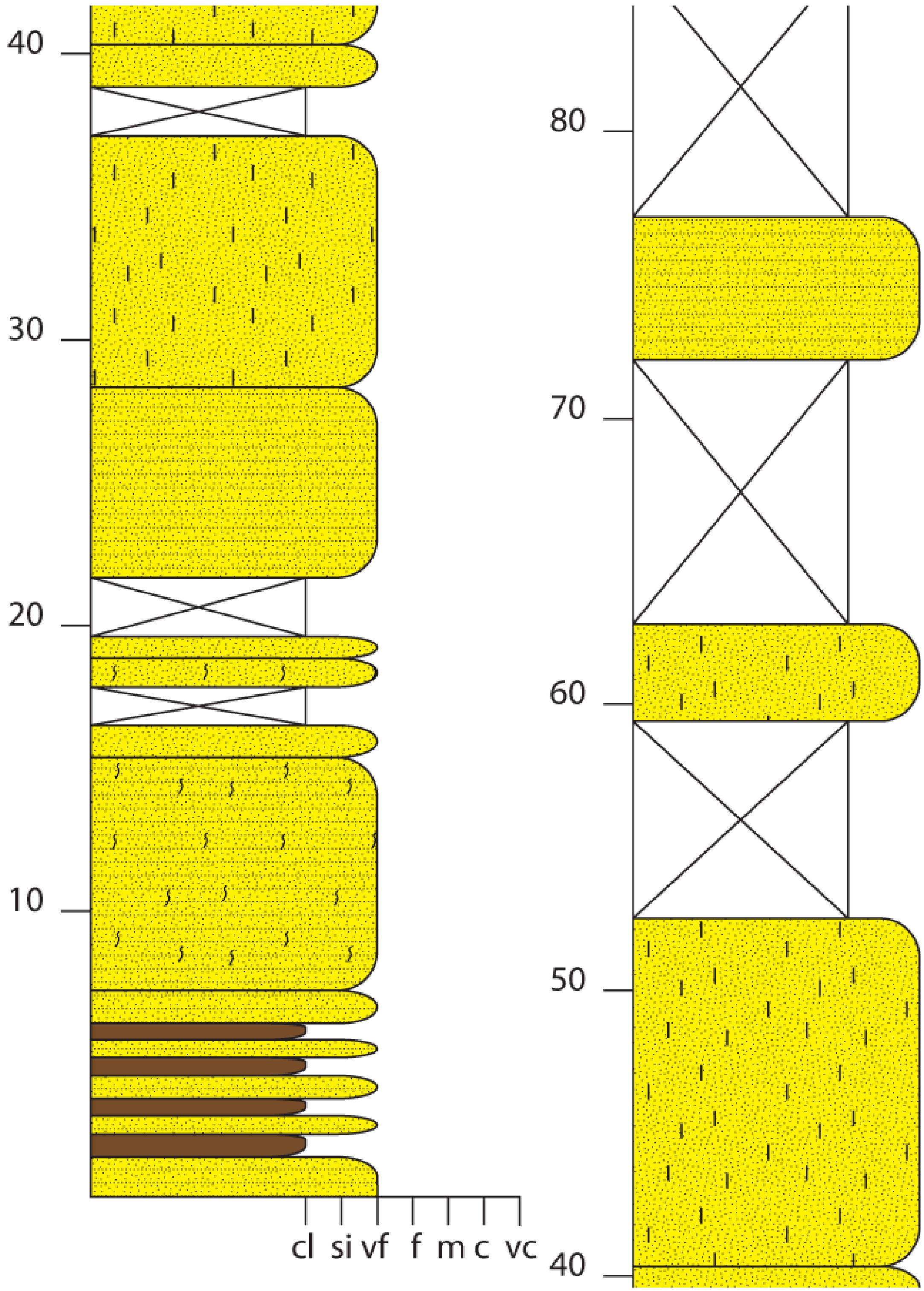
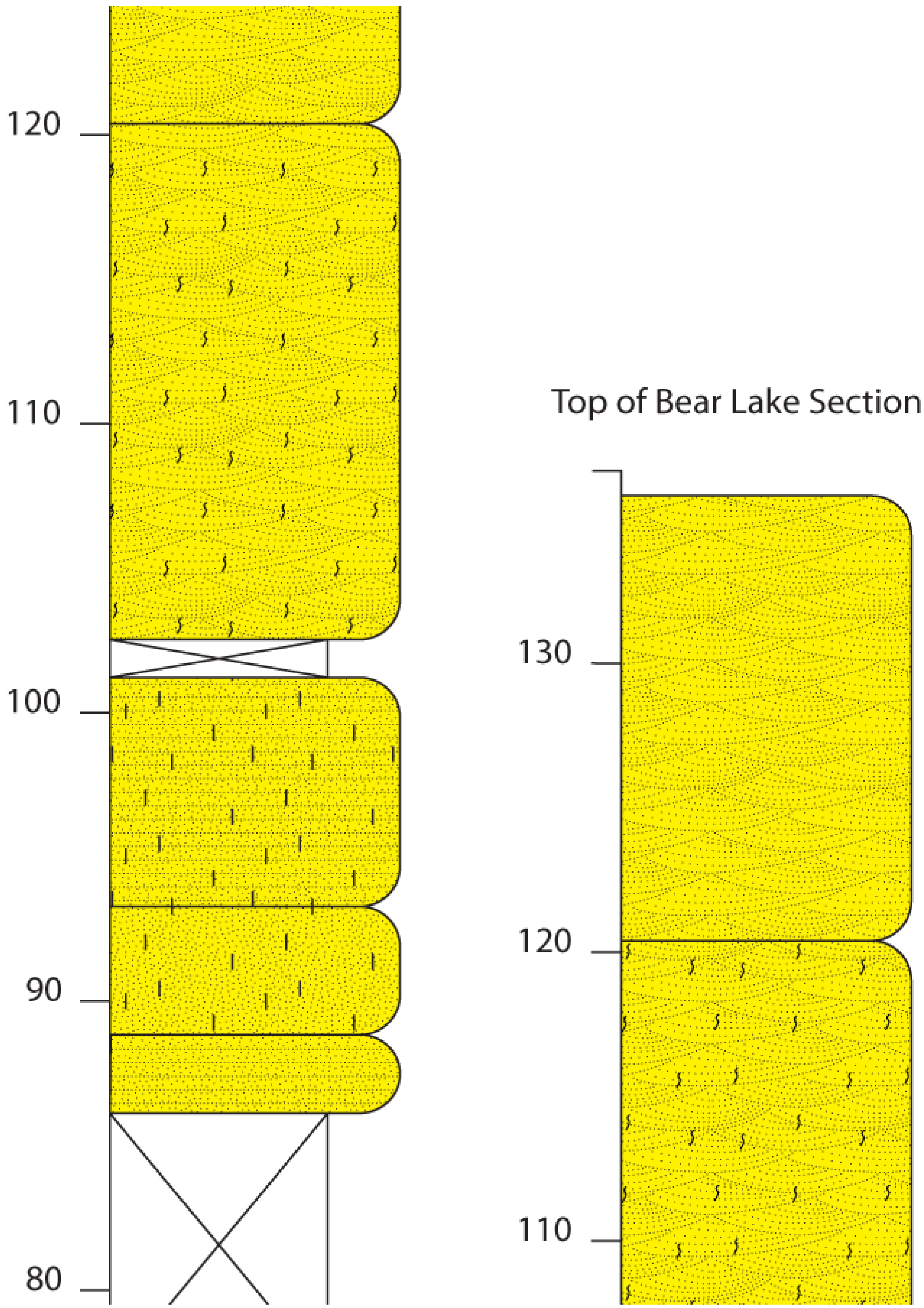
0.55
0.45
0.35
0.25
0.15
0
4
8
12
16
20
1200
1600
2000
2400
2800

STRATIGRAPHIC MEASURED SECTION




120
110
100
90
80
Top of Bear Lake Section
130
120
110

APPENDIX C

SODA SPRINGS SECTION

DATA TABLES

C-5 Soda Springs Base

Sample	$^{238}U/^{206}PB$	1σ (%)	$^{207}Pb/^{206}PB$	1σ (%)	$^{238}U/^{206}PB$ Age (Ma)	1σ	$^{207}Pb/^{206}PB$ Age (Ma)	1σ
				Soda Springs (Base) <10% Discordant				
SS7_1a	2.95	0.0186	0.1115	0.0099	1884	30	1824	18
SS7_2a	3.06	0.0181	0.1106	0.0106	1823	29	1809	19
SS7_3a	1.87	0.0195	0.1867	0.0149	2758	44	2713	24
SS7_16a	1.88	0.0220	0.1857	0.0133	2746	49	2704	22
SS7_17a	3.01	0.0193	0.1130	0.0118	1847	31	1849	21
SS7_30a	3.10	0.0203	0.1096	0.0110	1802	32	1793	20
SS7_34a	2.96	0.0229	0.1125	0.0116	1877	37	1840	21
SS7_35a	1.92	0.0292	0.1885	0.0089	2703	64	2729	15
SS7_37a	1.83	0.0207	0.1873	0.0107	2808	47	2719	18
SS7_42a	2.99	0.0189	0.1115	0.0122	1862	30	1823	22
SS7_46a	1.77	0.0211	0.1901	0.0097	2885	49	2743	16
SS7_51a	2.90	0.0215	0.1126	0.0100	1908	35	1842	18
SS7_65a	1.65	0.0226	0.2202	0.0102	3059	55	2982	16
SS7_82a	1.93	0.0304	0.1881	0.0120	2690	67	2725	20
SS7_105a	2.83	0.0211	0.1168	0.0096	1952	35	1908	17
SS7_109a	1.83	0.0219	0.1895	0.0104	2816	50	2738	17
SS7_116a	2.76	0.0196	0.1204	0.0116	1994	34	1962	21
SS7_123a	2.99	0.0215	0.1141	0.0156	1860	35	1865	28
SS7_126a	1.84	0.0219	0.1974	0.0151	2800	50	2805	25
SS7_128a	1.94	0.0342	0.1856	0.0146	2681	75	2704	24
SS7_129a	1.93	0.0338	0.1864	0.0147	2691	74	2711	24
SS7_130a	1.89	0.0224	0.1878	0.0111	2742	50	2723	18
SS7_134a	3.00	0.0222	0.1135	0.0093	1853	36	1856	17
SS7_137a	2.98	0.0234	0.1116	0.0105	1867	38	1825	19
SS7_138a	1.94	0.0345	0.1882	0.0147	2677	75	2727	24
SS7_139a	3.17	0.0301	0.1101	0.0113	1765	46	1802	20
SS7_144a	1.89	0.0214	0.1866	0.0089	2738	48	2713	15
SS7_149a	2.97	0.0227	0.1123	0.0153	1871	37	1837	27
SS7_163a	1.89	0.0231	0.1832	0.0096	2741	51	2682	16
SS7_164a	1.80	0.0205	0.1879	0.0090	2845	47	2724	15
SS7_165a	3.07	0.0212	0.1115	0.0152	1817	33	1823	27
SS7_167a	3.05	0.0241	0.1134	0.0100	1827	38	1854	18
SS7_173a	3.15	0.0346	0.1113	0.0157	1776	53	1821	28
SS7_174a	1.95	0.0348	0.1889	0.0151	2666	75	2733	25

SS7_177a	1.96	0.0224	0.1845	0.0155	2652	49	2693	25
SS7_180a	1.94	0.0294	0.1833	0.0107	2676	64	2683	18
SS7_181a	1.89	0.0331	0.1857	0.0127	2738	74	2704	21
SS7_182a	3.04	0.0192	0.1090	0.0089	1832	31	1782	16
SS7_185a	3.30	0.0339	0.1090	0.0151	1707	51	1782	27
SS7_186a	3.20	0.0283	0.1081	0.0113	1754	43	1767	21
SS7_193a	1.85	0.0256	0.1866	0.0126	2780	58	2713	21
SS7_198a	1.98	0.0212	0.1831	0.0154	2640	46	2681	25
SS7_199a	3.24	0.0307	0.1071	0.0119	1733	47	1751	22
SS7_200a	3.03	0.0338	0.1138	0.0149	1836	54	1860	27
SS7_205a	3.10	0.0361	0.1178	0.0464	1801	56	1923	81
SS7_206a	1.96	0.0344	0.1861	0.0146	2656	74	2708	24
SS7_209a	2.17	0.0292	0.1627	0.0109	2440	59	2484	18
SS7_212a	1.88	0.0228	0.1830	0.0098	2744	51	2681	16
SS7_214a	3.19	0.0345	0.1125	0.0154	1757	53	1840	28
SS7_216a	3.12	0.0328	0.1120	0.0163	1793	51	1832	29
SS7_221a	1.74	0.0239	0.2151	0.0156	2927	56	2944	25
SS7_222a	3.06	0.0283	0.1117	0.0112	1822	45	1828	20
SS7_235a	3.23	0.0281	0.1082	0.0111	1740	43	1770	20
SS7_241a	1.93	0.0230	0.1858	0.0148	2695	50	2705	24
SS7_245a	3.05	0.0313	0.1134	0.0116	1825	50	1855	21
SS7_247a	1.94	0.0286	0.1835	0.0111	2680	62	2685	18
SS7_251a	3.22	0.0303	0.1065	0.0115	1742	46	1740	21
SS7_257a	3.06	0.0203	0.1130	0.0150	1820	32	1848	27
SS7_261a	1.94	0.0302	0.1886	0.0125	2679	66	2730	20
SS7_262a	1.98	0.0222	0.1820	0.0149	2635	48	2671	24
SS7_264a	2.94	0.0223	0.1101	0.0096	1887	36	1801	17
SS7_267a	1.91	0.0228	0.1854	0.0156	2713	50	2702	25
SS7_268a	1.93	0.0204	0.1873	0.0152	2695	45	2718	25
SS7_270a	3.00	0.0220	0.1078	0.0099	1853	35	1763	18
SS7_277a	3.06	0.0216	0.1131	0.0150	1824	34	1850	27
SS7_286a	1.97	0.0197	0.1864	0.0151	2641	43	2711	25
SS7_292a	2.00	0.0220	0.1823	0.0149	2611	47	2674	24
SS7_294a	3.10	0.0241	0.1100	0.0094	1804	38	1800	17
SS7_304a	1.91	0.0253	0.1877	0.0086	2717	56	2722	14
SS7_306a	1.93	0.0210	0.1840	0.0142	2693	46	2689	23
SS7_312a	3.18	0.0324	0.1118	0.0101	1762	50	1829	18
SS7_313a	2.00	0.0275	0.1874	0.0089	2613	59	2719	15
SS7_315a	1.90	0.0283	0.1960	0.0086	2725	63	2793	14
SS7_317a	3.07	0.0189	0.1108	0.0144	1818	30	1813	26

SS7_319a	2.05	0.0310	0.1771	0.0086	2558	65	2626	14
SS7_322a	3.05	0.0211	0.1139	0.0149	1829	33	1863	27
SS7_326a	1.67	0.0262	0.2205	0.0086	3019	63	2984	14
SS7_327a	1.98	0.0196	0.1857	0.0144	2635	42	2704	24
SS7_335a	1.90	0.0212	0.1872	0.0143	2724	47	2718	23
SS7_340a	1.96	0.0236	0.1879	0.0154	2655	51	2724	25
SS7_341a	1.74	0.0338	0.1994	0.0109	2933	79	2821	18
SS7_343a	1.78	0.0311	0.2006	0.0104	2871	72	2831	17
SS7_345a	1.84	0.0222	0.1863	0.0145	2802	50	2710	24
SS7_350a	1.94	0.0249	0.1845	0.0081	2681	54	2693	13
SS7_364a	3.30	0.0197	0.1091	0.0149	1705	29	1784	27
SS7_365a	1.93	0.0251	0.1860	0.0145	2695	55	2708	24
SS7_366a	3.06	0.0264	0.1142	0.0111	1821	42	1867	20
SS7_368a	1.93	0.0195	0.1815	0.0147	2686	43	2666	24
SS7_369a	1.37	0.0292	0.3207	0.0091	3539	79	3573	14
SS7_388a	1.99	0.0264	0.1786	0.0093	2624	57	2640	15
SS7_389a	3.08	0.0238	0.1148	0.0160	1812	38	1877	29
SS7_395a	1.92	0.0200	0.1841	0.0143	2698	44	2690	23
SS7_435a	2.05	0.0213	0.1823	0.0148	2566	45	2674	24
SS7_455a	3.01	0.0225	0.1157	0.0145	1847	36	1891	26
			>10% Discordant					
SS7_155a	2.40	0.0322	0.1872	0.0107	2243	61	2717	18
SS7_158a	6.64	0.0345	0.1397	0.0144	904	29	2224	25
SS7_201a	2.30	0.0290	0.1823	0.0106	2329	57	2674	17
SS7_263a	3.59	0.0768	0.2030	0.0184	1583	107	2851	30
SS7_293a	7.97	0.0392	0.1813	0.0080	762	28	2665	13
SS7_374a	2.62	0.0265	0.2016	0.0083	2085	47	2839	13
SS7_445a	2.78	0.0206	0.1459	0.0152	1983	35	2298	26

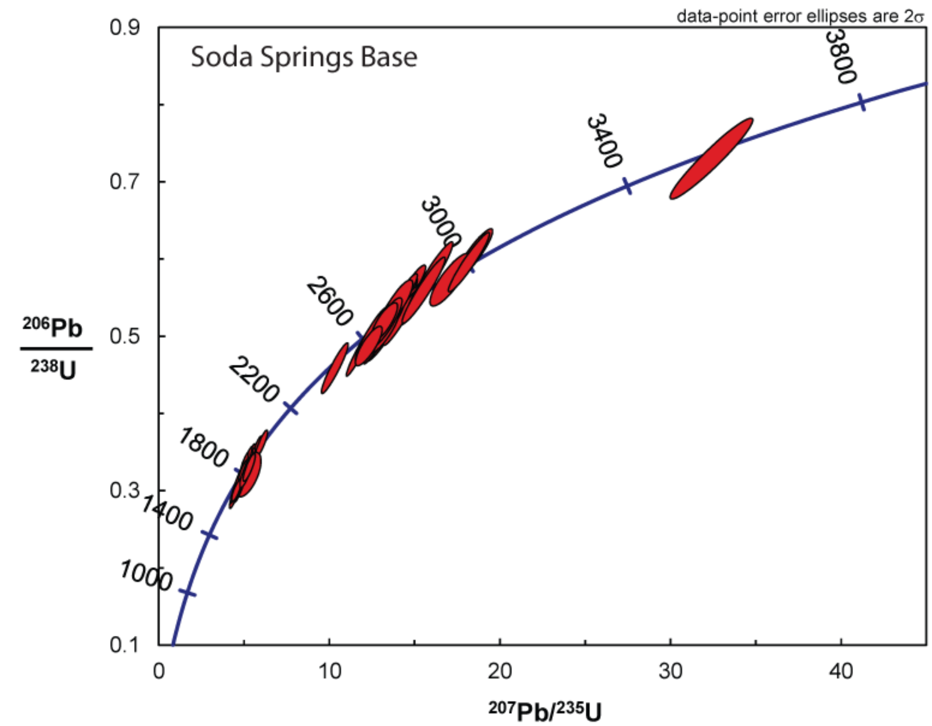
C-6 Soda Springs Top

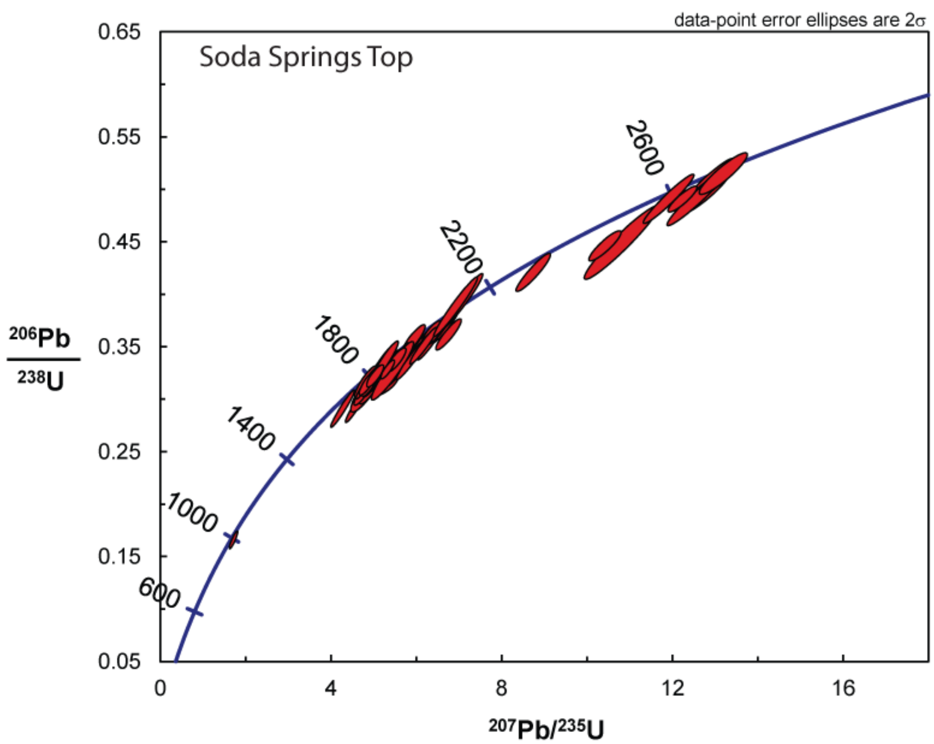
Sample	**$^{238}U/^{206}PB$**	**1σ (%)**	**$^{207}Pb/^{206}PB$**	**1σ (%)**	**$^{238}U/^{206}PB$ Age (Ma)**	**1σ**	**$^{207}Pb/^{206}PB$ Age (Ma)**	**1σ**
			Soda Springs (Top) <10% Discordant					
SS2_1a	5.99	0.0203	0.0741	0.0091	996	19	1043	18
SS2_2a	2.89	0.0199	0.1191	0.0059	1915	33	1942	10
SS2_3a	1.98	0.0193	0.1833	0.0065	2640	42	2683	11
SS2_4a	3.15	0.0186	0.1171	0.0307	1779	29	1912	54
SS2_7a	2.01	0.0181	0.1854	0.0082	2607	39	2702	13
SS2_9a	3.04	0.0190	0.1171	0.0080	1834	30	1913	14
SS2_10a	3.04	0.0165	0.1144	0.0071	1834	26	1870	13
SS2_12a	2.37	0.0174	0.1499	0.0070	2270	33	2345	12
SS2_14a	3.15	0.0165	0.1119	0.0065	1780	26	1830	12
SS2_15a	2.79	0.0166	0.1199	0.0087	1973	28	1955	16
SS2_16a	3.17	0.0210	0.1146	0.0151	1768	32	1874	27
SS2_18a	1.97	0.0178	0.1849	0.0063	2644	39	2698	10
SS2_19a	3.03	0.0235	0.1216	0.0118	1838	37	1980	21
SS2_20a	3.11	0.0180	0.1139	0.0098	1798	28	1862	18
SS2_21a	3.18	0.0184	0.1142	0.0114	1761	28	1867	20
SS2_22a	2.82	0.0230	0.1257	0.0085	1954	39	2039	15
SS2_23a	2.22	0.0320	0.1738	0.0095	2398	64	2595	16
SS2_25a	2.99	0.0178	0.1189	0.0092	1860	29	1940	16
SS2_27a	3.09	0.0240	0.1170	0.0175	1810	38	1911	31
SS2_30a	2.69	0.0194	0.1299	0.0079	2038	34	2096	14
SS2_32a	3.15	0.0222	0.1126	0.0119	1776	34	1842	21
SS2_33a	3.13	0.0209	0.1142	0.0096	1788	33	1867	17
SS2_34a	2.70	0.0187	0.1290	0.0065	2029	32	2085	11
SS2_35a	2.95	0.0196	0.1184	0.0049	1880	32	1932	9
SS2_37a	3.08	0.0188	0.1150	0.0058	1811	30	1881	10
SS2_38a	3.11	0.0176	0.1141	0.0069	1797	27	1865	12
SS2_41a	2.74	0.0120	0.1260	0.0068	2007	21	2043	12
SS2_42a	3.40	0.0206	0.1128	0.0068	1663	30	1845	12
SS2_44a	3.13	0.0223	0.1134	0.0107	1788	35	1854	19
SS2_45a	3.08	0.0269	0.1170	0.0091	1813	42	1911	16
SS2_47a	3.08	0.0167	0.1129	0.0084	1811	26	1847	15
SS2_49a	2.82	0.0188	0.1290	0.0056	1958	32	2084	10
SS2_50a	3.11	0.0197	0.1210	0.0084	1796	31	1972	15
SS2_54a	3.05	0.0270	0.1172	0.0101	1828	43	1914	18
SS2_57a	3.15	0.0205	0.1131	0.0097	1778	32	1849	17

SS2_58a	3.08	0.0195	0.1141	0.0077	1812	31	1866	14
SS2_59a	3.07	0.0355	0.1127	0.0109	1818	56	1844	20
SS2_60a	3.16	0.0120	0.1126	0.0056	1770	18	1841	10
SS2_65a	3.08	0.0196	0.1152	0.0067	1814	31	1882	12
SS2_66a	3.03	0.0210	0.1151	0.0056	1839	33	1881	10
SS2_69a	3.08	0.0114	0.1145	0.0049	1811	18	1872	9
SS2_73a	3.13	0.0206	0.1152	0.0066	1785	32	1883	12
SS2_74a	2.03	0.0219	0.1850	0.0062	2584	46	2698	10
SS2_75a	3.01	0.0181	0.1169	0.0061	1852	29	1909	11
SS2_76a	3.16	0.0234	0.1128	0.0085	1775	36	1845	15
SS2_79a	2.99	0.0123	0.1186	0.0069	1858	20	1936	12
SS2_80a	3.20	0.0308	0.1130	0.0163	1753	47	1848	29
SS2_81a	3.00	0.0125	0.1167	0.0089	1854	20	1906	16
SS2_88a	3.12	0.0152	0.1123	0.0078	1793	24	1837	14
SS2_89a	3.21	0.0119	0.1116	0.0077	1747	18	1826	14
SS2_92a	3.15	0.0190	0.1095	0.0091	1780	30	1790	17
SS2_96a	3.03	0.0234	0.1186	0.0075	1841	37	1935	13
SS2_97a	3.02	0.0135	0.1179	0.0078	1846	22	1924	14
SS2_98a	3.42	0.0251	0.1058	0.0070	1652	37	1728	13
SS2_99a	3.13	0.0189	0.1121	0.0108	1789	29	1834	19
SS2_104a	3.23	0.0157	0.1146	0.0094	1738	24	1874	17
SS2_106a	3.22	0.0177	0.1144	0.0109	1742	27	1870	20
SS2_110a	3.11	0.0173	0.1149	0.0072	1796	27	1878	13
SS2_114a	2.76	0.0112	0.1284	0.0066	1992	19	2076	12
SS2_116a	3.10	0.0214	0.1124	0.0077	1801	34	1838	14
SS2_117a	3.14	0.0184	0.1143	0.0071	1783	29	1868	13
SS2_119a	3.14	0.0199	0.1133	0.0120	1781	31	1852	21
SS2_120a	3.01	0.0131	0.1166	0.0063	1850	21	1904	11
SS2_122a	3.13	0.0142	0.1110	0.0075	1787	22	1816	14
SS2_125a	2.24	0.0132	0.1689	0.0067	2382	26	2547	11
SS2_128a	2.99	0.0172	0.1160	0.0058	1857	28	1896	10
SS2_129a	3.08	0.0138	0.1142	0.0103	1814	22	1867	18
SS2_130a	3.28	0.0130	0.1118	0.0084	1715	20	1829	15
SS2_132a	3.14	0.0188	0.1133	0.0079	1781	29	1853	14
SS2_134a	3.06	0.0130	0.1169	0.0087	1824	21	1909	16
SS2_136a	1.94	0.0157	0.1852	0.0072	2682	34	2700	12
SS2_137a	3.18	0.0171	0.1104	0.0060	1762	26	1806	11
SS2_139a	3.16	0.0145	0.1111	0.0095	1773	22	1817	17
SS2_140a	3.05	0.0348	0.1202	0.0130	1828	55	1959	23
SS2_141a	2.03	0.0103	0.1803	0.0052	2579	22	2655	9

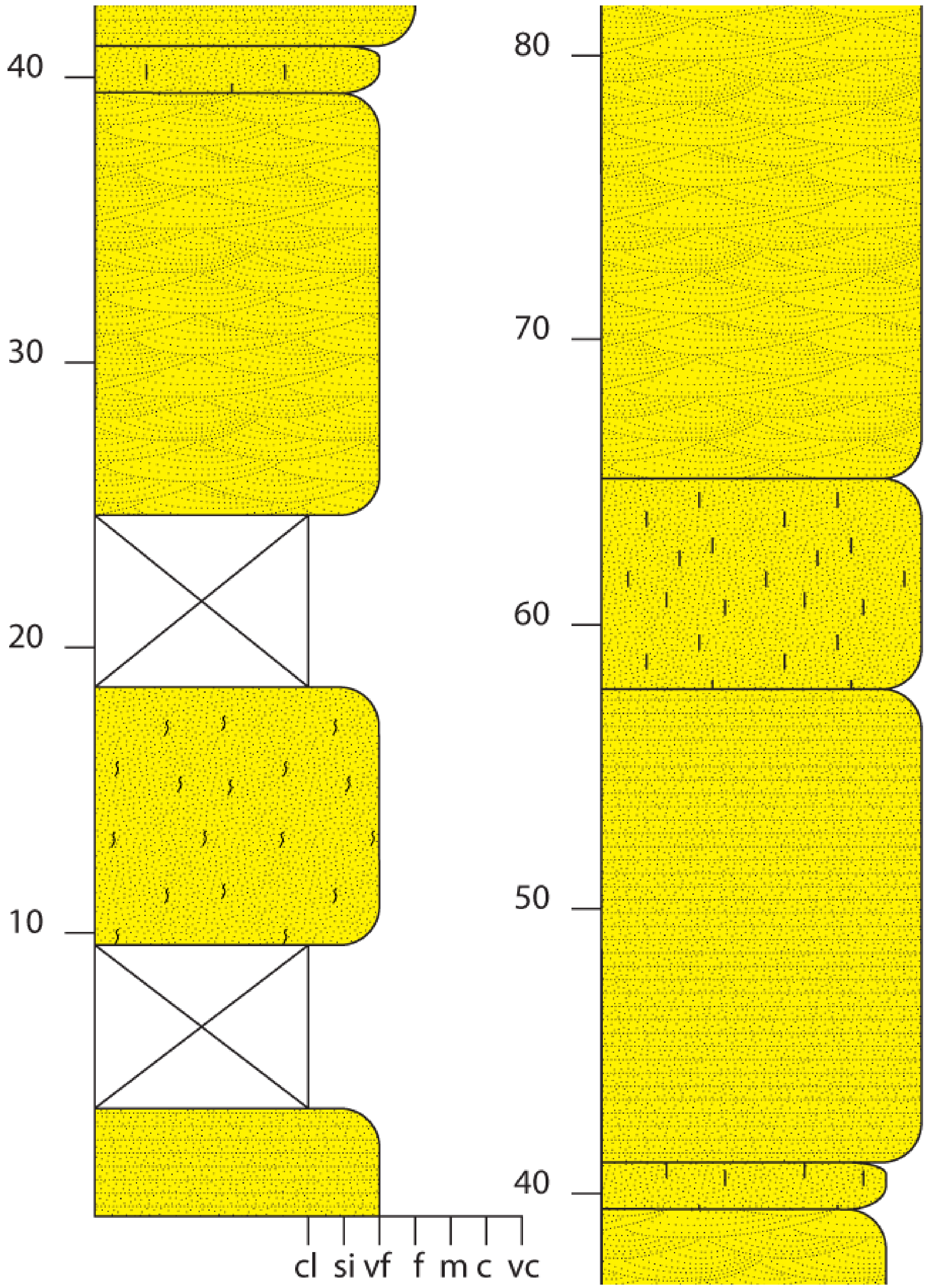
SS2_143a	2.93	0.0261	0.1258	0.0072	1891	43	2040	13
SS2_144a	2.97	0.0237	0.1130	0.0085	1871	38	1848	15
SS2_145a	2.54	0.0280	0.1297	0.0075	2139	51	2094	13
SS2_146a	2.95	0.0139	0.1182	0.0090	1881	23	1930	16
SS2_147a	2.76	0.0162	0.1349	0.0076	1996	28	2162	13
SS2_148a	2.84	0.0206	0.1269	0.0067	1945	34	2056	12
SS2_149a	2.57	0.0298	0.1287	0.0071	2121	54	2080	12
SS2_150a	2.03	0.0193	0.1755	0.0056	2578	41	2611	9
SS2_151a	3.03	0.0112	0.1170	0.0068	1836	18	1911	12
SS2_153a	3.09	0.0134	0.1129	0.0089	1805	21	1847	16
			>10% Discordant					
SS2_5a	5.59	0.0169	0.1698	0.0061	1060	17	2556	10
SS2_6a	3.29	0.0321	0.1529	0.0252	1710	48	2378	42
SS2_13a	3.28	0.0204	0.1190	0.0100	1717	31	1942	18
SS2_17a	4.29	0.0218	0.1353	0.0073	1351	27	2167	13
SS2_24a	3.15	0.0178	0.1238	0.0089	1777	28	2011	16
SS2_31a	3.47	0.0101	0.1148	0.0030	1635	15	1877	5
SS2_36a	11.27	0.0212	0.1171	0.0060	548	11	1912	11
SS2_40a	3.71	0.0126	0.1195	0.0050	1537	17	1948	9
SS2_43a	3.30	0.0331	0.1580	0.0199	1708	49	2434	33
SS2_55a	5.09	0.0192	0.1661	0.0040	1155	20	2519	7
SS2_61a	3.54	0.0243	0.1202	0.0094	1606	34	1959	17
SS2_67a	3.08	0.0151	0.1277	0.0102	1812	24	2067	18
SS2_78a	5.01	0.0216	0.1654	0.0082	1174	23	2512	14
SS2_95a	3.57	0.0182	0.1564	0.0102	1590	26	2417	17
SS2_127a	3.19	0.0158	0.1250	0.0120	1759	24	2028	21
SS2_138a	3.60	0.0245	0.1165	0.0058	1580	34	1903	10
SS2_152a	4.09	0.0146	0.2195	0.0044	1409	19	2977	7

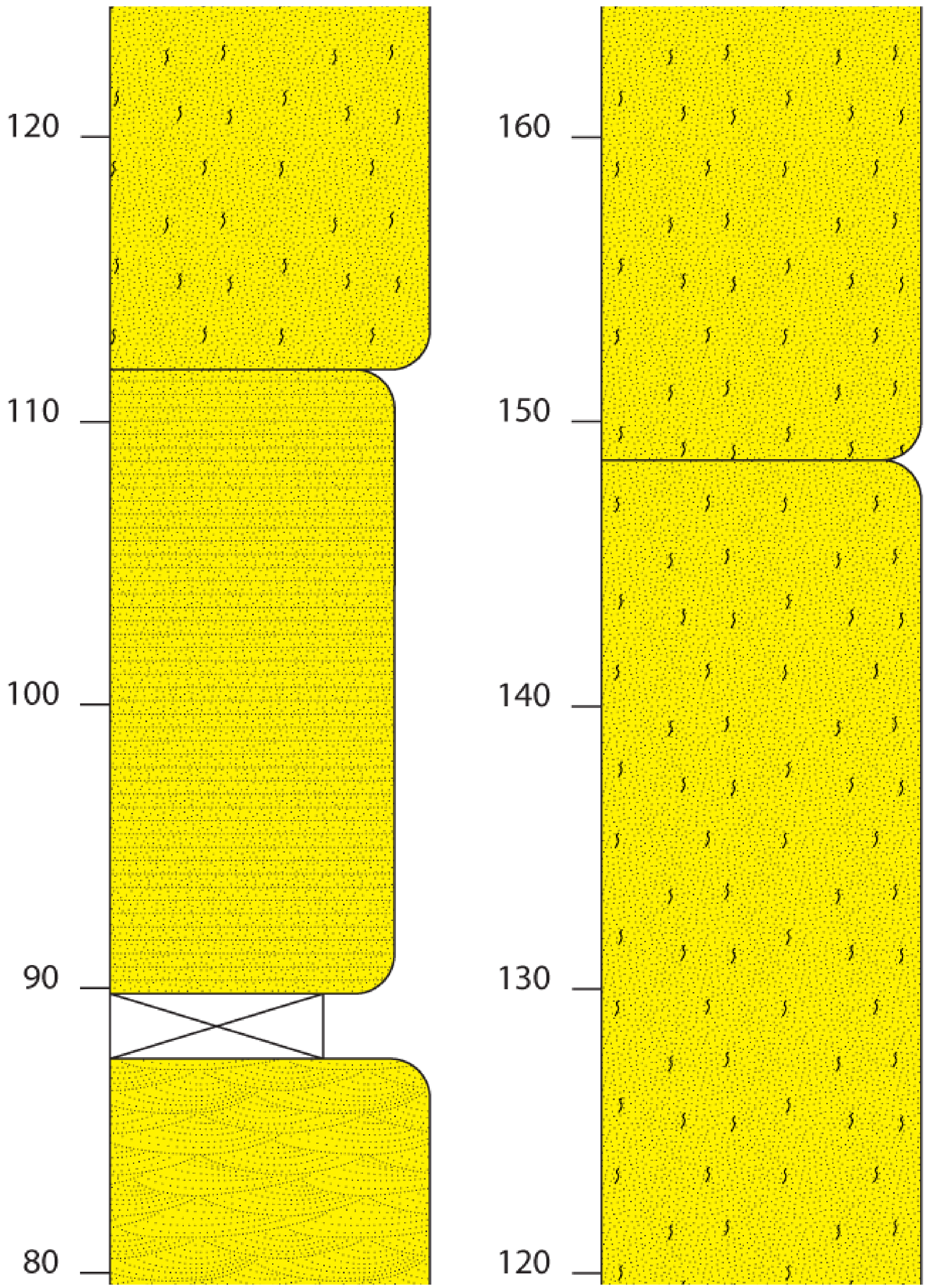
WETHERILL PLOTS





STRATIGRAPHIC MEASURED SECTION

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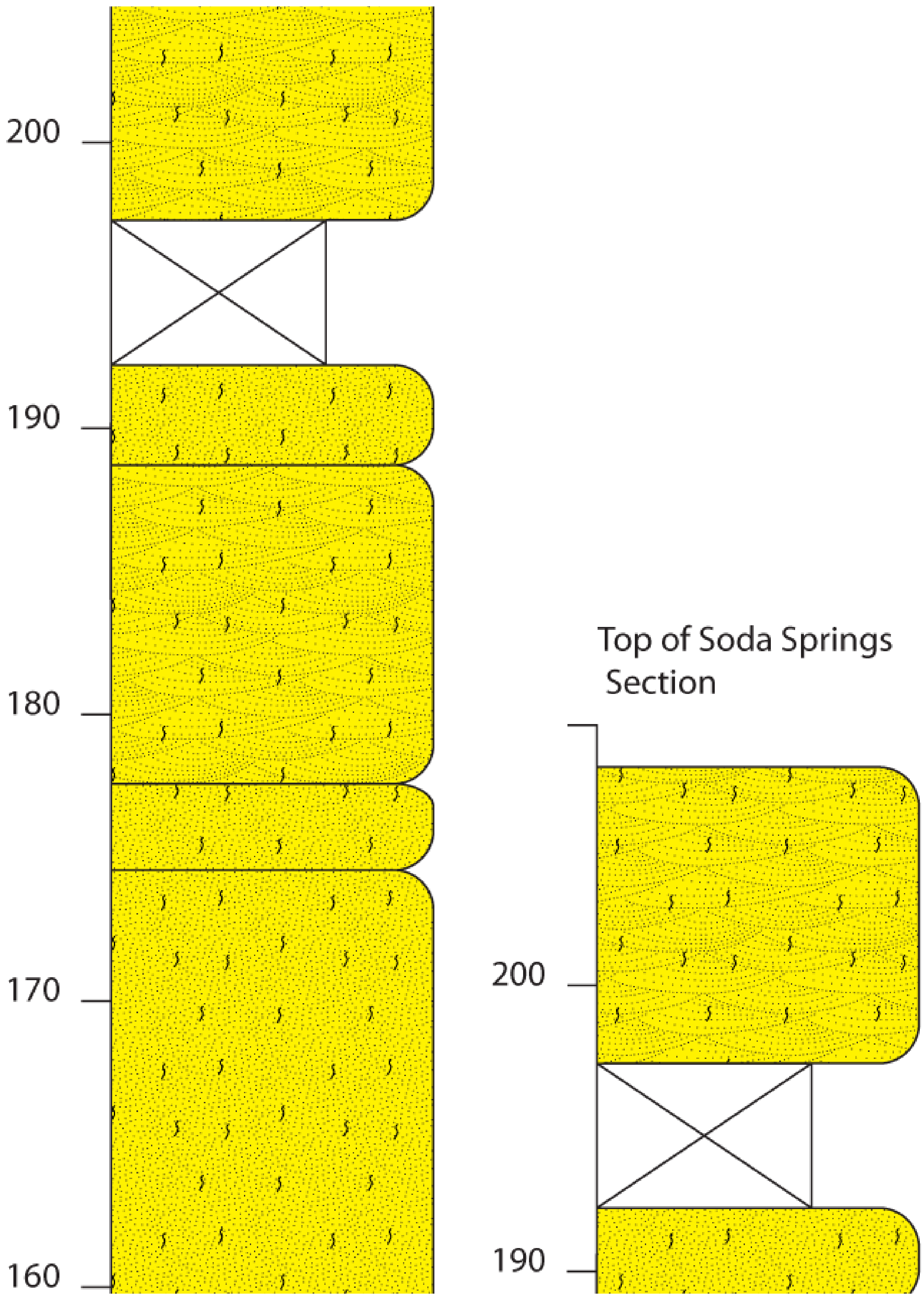
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APPENDIX D

LAVA HOT SPRINGS SECTION

DATA TABLES

C-7 Lava Hot Springs Base

Sample	$^{238}U/^{206}PB$	1σ (%)	$^{207}Pb/^{206}PB$	1σ (%)	$^{238}U/^{206}PB$ Age (Ma)	1σ	$^{207}Pb/^{206}PB$ Age (Ma)	1σ
			Lava Hot Springs (Base) <10% Discordant					
LHS2_55a	2.89	0.0376	0.1143	0.0100	1917	62	1868	18
LHS2_63a	1.84	0.0415	0.1919	0.0088	2793	93	2759	14
LHS2_97a	2.06	0.0420	0.1945	0.0075	2551	88	2781	12
LHS2_108a	2.97	0.0387	0.1151	0.0082	1872	63	1881	15
LHS2_110a	2.00	0.0176	0.1888	0.0080	2612	38	2732	13
LHS2_114a	3.08	0.0381	0.1093	0.0098	1810	60	1788	18
LHS2_135a	1.90	0.0372	0.1837	0.0084	2723	82	2686	14
LHS2_140a	1.91	0.0375	0.1858	0.0076	2711	83	2705	12
LHS2_153a_top	1.97	0.0180	0.1807	0.0085	2651	39	2659	14
LHS2_156a	1.87	0.0369	0.1866	0.0077	2757	82	2713	13
LHS2_164a	1.92	0.0365	0.1845	0.0106	2707	80	2694	17
LHS2_166a	1.96	0.0168	0.1833	0.0064	2663	37	2683	11
LHS2_171a	1.99	0.0270	0.1810	0.0097	2624	58	2662	16
LHS2_242a	1.92	0.0238	0.1865	0.0109	2702	52	2711	18
LHS2_244a	1.86	0.0384	0.1882	0.0098	2779	86	2726	16
LHS2_246a	1.83	0.0318	0.1994	0.0098	2805	72	2821	16
LHS2_251a	3.15	0.0135	0.1083	0.0060	1777	21	1772	11
LHS2_265a	1.98	0.0236	0.1846	0.0083	2640	51	2694	14
LHS2_276a	1.88	0.0154	0.1896	0.0062	2744	34	2739	10
LHS2_278a	1.76	0.0250	0.1797	0.0084	2898	58	2650	14
LHS2_280a	1.79	0.0314	0.2010	0.0091	2864	72	2835	15
LHS2_282a	2.72	0.0278	0.1210	0.0159	2018	48	1971	28
LHS2_290a	2.05	0.0371	0.1838	0.0107	2565	78	2687	18
LHS2_295a	2.85	0.0271	0.1138	0.0091	1937	45	1861	16
LHS2_300a	3.01	0.0430	0.1098	0.0132	1849	69	1796	24
LHS2_301a	1.84	0.0329	0.2237	0.0069	2801	74	3008	11
LHS2_303a	2.10	0.0365	0.1735	0.0075	2514	75	2592	13
LHS2_304a	1.84	0.0363	0.1993	0.0074	2800	82	2820	12
LHS2_312a	2.66	0.0560	0.1216	0.0109	2057	98	1980	19
LHS2_314a	3.00	0.0178	0.1123	0.0063	1856	29	1837	11
LHS2_318a	3.25	0.0257	0.1076	0.0104	1728	39	1760	19
LHS2_320a	3.08	0.0390	0.1153	0.0124	1813	61	1885	22
LHS2_322a	2.96	0.0198	0.1142	0.0070	1877	32	1867	13
LHS2_324a	1.95	0.0392	0.1796	0.0106	2674	85	2649	17

LHS2_335a	1.90	0.0202	0.1851	0.0065	2727	45	2699	11
LHS2_339a	2.02	0.0300	0.1888	0.0100	2589	64	2732	16
LHS2_342a	1.80	0.0413	0.2042	0.0120	2843	94	2860	19
LHS2_349a	1.89	0.0372	0.1836	0.0087	2737	82	2685	14
LHS2_350a	1.80	0.0607	0.2168	0.0123	2845	138	2957	20
LHS2_352a	3.02	0.0251	0.1130	0.0096	1845	40	1849	17
LHS2_357a	1.90	0.0367	0.1834	0.0103	2722	81	2684	17
LHS2_359a	2.09	0.0254	0.1656	0.0087	2518	53	2513	14
LHS2_360a	1.89	0.0405	0.1851	0.0063	2740	90	2699	10
LHS2_362a	2.68	0.0395	0.1162	0.0069	2044	69	1898	12
LHS2_364a	1.88	0.0405	0.1859	0.0110	2750	90	2706	18
LHS2_367a	1.80	0.0266	0.1870	0.0094	2850	61	2716	15
LHS2_376a	1.78	0.0427	0.1881	0.0070	2879	98	2726	12
LHS2_377a	3.05	0.0334	0.1192	0.0088	1826	53	1945	16
LHS2_380a	1.65	0.0476	0.2277	0.0212	3052	115	3036	34
LHS2_385a	2.18	0.0160	0.1734	0.0059	2432	32	2591	10
LHS2_398a	3.04	0.0365	0.1118	0.0107	1831	58	1828	19
LHS2_414a	1.83	0.0186	0.1882	0.0059	2812	42	2727	10
LHS2_417a	1.72	0.0402	0.2007	0.0070	2956	95	2832	11
LHS2_423a	1.97	0.0243	0.1861	0.0062	2648	53	2708	10
LHS2_428a_r	1.88	0.0403	0.1874	0.0110	2744	89	2720	18
LHS2_433a	2.65	0.0411	0.1160	0.0066	2063	72	1896	12
LHS2_434a	1.86	0.0376	0.1899	0.0089	2768	84	2741	14
LHS2_435a	1.95	0.0402	0.1781	0.0105	2667	87	2635	17
LHS2_436a	2.92	0.0196	0.1145	0.0063	1899	32	1872	11
LHS2_437a	3.41	0.0257	0.1090	0.0097	1658	38	1782	18
LHS2_443a	2.90	0.0145	0.1132	0.0063	1908	24	1852	11
LHS2_446a	3.29	0.0370	0.1097	0.0088	1711	55	1795	16
LHS2_453a	1.78	0.0366	0.1996	0.0103	2868	84	2823	17
LHS2_456a	1.81	0.0395	0.1906	0.0064	2831	90	2747	10
LHS2_462a	1.95	0.0147	0.1849	0.0053	2664	32	2698	9
LHS2_471a	3.01	0.0373	0.1098	0.0117	1849	60	1796	21
LHS2_472a	1.68	0.0396	0.2030	0.0064	3016	95	2850	10
LHS2_474a	3.08	0.0364	0.1145	0.0110	1813	57	1872	20
LHS2_490a	1.95	0.0380	0.1824	0.0117	2670	82	2675	19
LHS2_499a	1.88	0.0378	0.1992	0.0109	2745	84	2820	18
LHS2_504a	1.81	0.0398	0.1883	0.0062	2830	91	2727	10
LHS2_506a	1.86	0.0362	0.1857	0.0115	2775	81	2704	19
LHS2_510a	3.12	0.0393	0.1110	0.0125	1793	61	1816	23
LHS2_511a	1.95	0.0357	0.1856	0.0105	2667	77	2703	17

LHS2_741a_bottom	1.96	0.0388	0.1872	0.0088	2658	84	2718	14
LHS2_741a_top	3.00	0.0372	0.1118	0.0081	1852	60	1829	15
			>10% Discordant					
LHS2_1a	4.36	0.1603	0.2293	0.0348	1330	190	3047	55
LHS2_3a	3.51	0.0547	0.1245	0.0206	1618	78	2022	36
LHS2_5a	2.71	0.1306	0.2611	0.0246	2024	223	3253	38
LHS2_12a	#VALUE!	######	0.2334	0.0199	#VALUE!	###	3076	31
LHS2_16a	3.94	0.0582	0.1232	0.0171	1458	75	2003	30
LHS2_18a	3.98	0.0899	0.1529	0.0228	1444	115	2379	38
LHS2_20a	2.93	0.1588	0.2262	0.0115	1892	255	3025	18
LHS2_25a	#VALUE!	######	0.2125	0.0152	#VALUE!	###	2924	24
LHS2_28a	#VALUE!	######	0.2598	0.0188	#VALUE!	###	3246	29
LHS2_49a	3.71	0.0728	0.1252	0.0108	1539	99	2031	19
LHS2_52a	4.08	0.0766	0.1441	0.0245	1413	96	2277	42
LHS2_58a	#VALUE!	######	0.2978	0.0240	#VALUE!	###	3459	37
LHS2_62a	2.24	0.0374	0.1907	0.0092	2383	74	2748	15
LHS2_69a	#VALUE!	######	0.2346	0.0228	#VALUE!	###	3084	36
LHS2_73a	#VALUE!	######	0.1956	0.0379	#VALUE!	###	2790	61
LHS2_89a	#VALUE!	######	0.2245	0.0159	#VALUE!	###	3014	25
LHS2_96a	#VALUE!	######	0.2158	0.0157	#VALUE!	###	2950	25
LHS2_119a	4.48	0.0971	0.2117	0.0150	1300	113	2919	24
LHS2_153a_bottom	2.59	0.0970	0.1996	0.0119	2105	172	2823	19
LHS2_189a	2.73	0.0980	0.2002	0.0131	2011	167	2828	21
LHS2_190a	2.57	0.0412	0.1166	0.0121	2121	74	1904	22
LHS2_202a	4.38	0.0933	0.1230	0.0160	1326	111	2000	28
LHS2_227a	4.16	0.0488	0.1158	0.0083	1387	61	1893	15
LHS2_237a	2.32	0.0579	0.1950	0.0075	2308	111	2784	12
LHS2_261a	2.16	0.0286	0.1981	0.0084	2454	58	2810	14
LHS2_274a	3.65	0.0483	0.1896	0.0091	1562	67	2738	15
LHS2_317a	#VALUE!	######	0.2198	0.0164	#VALUE!	###	2979	26
LHS2_329a	3.61	0.0306	0.1144	0.0063	1577	43	1870	11
LHS2_334a	#VALUE!	######	0.2295	0.0221	#VALUE!	###	3048	35
LHS2_338a	2.08	0.0755	0.2076	0.0132	2530	156	2887	21
LHS2_374a	#VALUE!	######	0.2306	0.0177	#VALUE!	###	3056	28
LHS2_383a	3.96	0.0676	0.1219	0.0123	1452	87	1985	22
LHS2_397a	#VALUE!	######	0.2491	0.0205	#VALUE!	###	3179	32
LHS2_400a	1.63	0.0433	0.1885	0.0062	3077	105	2729	10
LHS2_418a	3.02	0.0383	0.1837	0.0093	1843	61	2687	15
LHS2_485a	2.36	0.0487	0.1859	0.0057	2274	93	2706	9
LHS2_486a	2.06	0.0681	0.2094	0.0093	2552	142	2901	15

LHS2_500a	#VALUE!	######	0.1810	0.0368	#VALUE!	###	2662	60

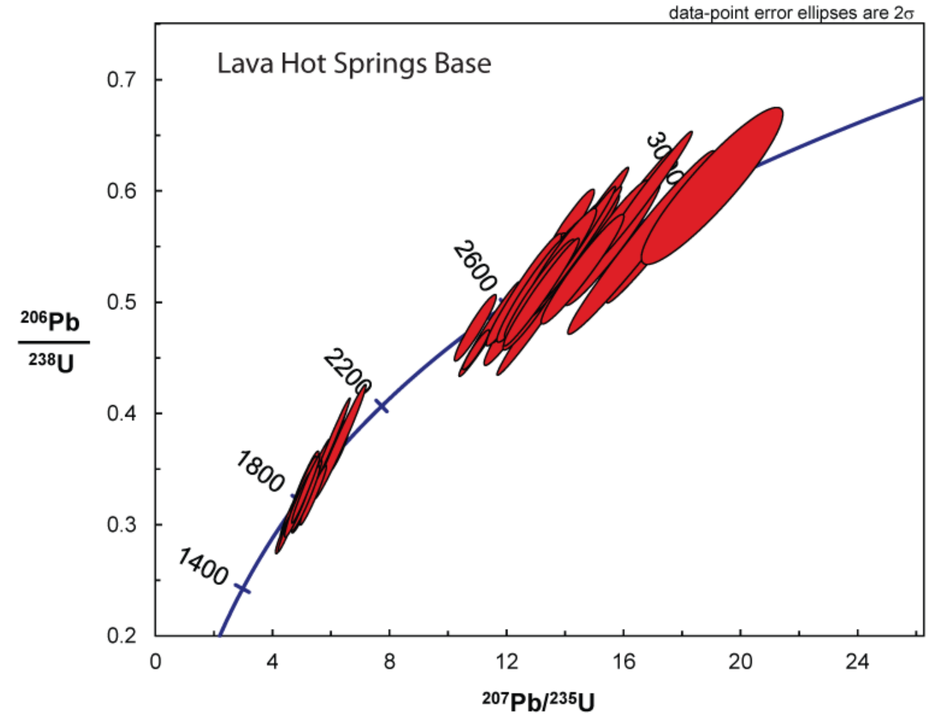
C-8 Lava Hot Springs Top

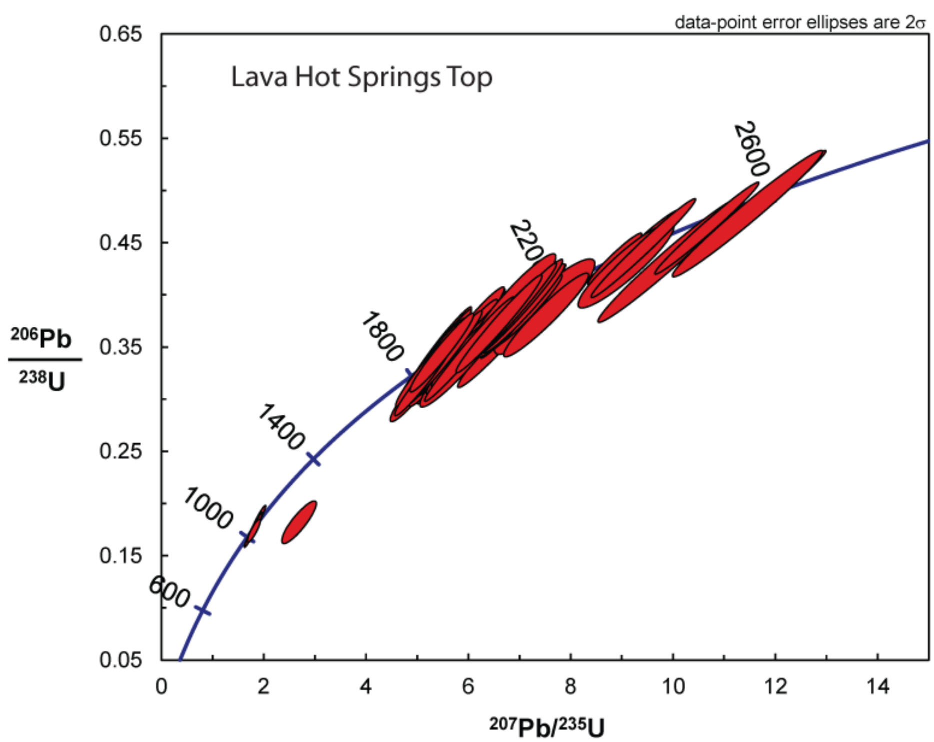
Sample	$^{238}U/^{206}PB$	1σ (%)	$^{207}Pb/^{206}PB$	1σ (%)	$^{238}U/^{206}PB$ Age (Ma)	1σ	$^{207}Pb/^{206}PB$ Age (Ma)	1σ
			Lava Hot Springs (Top) <10% Discordant					
LHS1_1a	3.01	0.0287	0.1123	0.0081	2009	42	2015	15
LHS1_2a	2.76	0.0511	0.1285	0.0087	1995	58	2051	13
LHS1_3a	3.00	0.0419	0.1179	0.0108	1057	28	1046	20
LHS1_4a	2.73	0.0242	0.1241	0.0088	1886	77	1844	17
LHS1_10a	2.76	0.0342	0.1266	0.0073	1873	54	1912	14
LHS1_13a	2.82	0.0486	0.1347	0.0114	2329	45	2318	11
LHS1_17a	2.30	0.0232	0.1476	0.0065	1941	81	1949	17
LHS1_18a	2.85	0.0488	0.1195	0.0093	1994	87	2078	15
LHS1_27a	2.85	0.0272	0.1176	0.0053	1856	67	1924	19
LHS1_32a	2.97	0.0335	0.1171	0.0080	1956	82	2161	20
LHS1_33a	5.45	0.0452	0.1060	0.0251	1847	46	1837	15
LHS1_34a	2.88	0.0453	0.1200	0.0079	1870	64	1878	13
LHS1_39a	2.59	0.0476	0.1328	0.0086	1925	73	1930	13
LHS1_42a	5.48	0.0385	0.0733	0.0104	1841	66	1990	21
LHS1_68a	3.03	0.0416	0.1223	0.0117	1936	45	1921	10
LHS1_73a	5.61	0.0293	0.0742	0.0101	1081	38	1021	21
LHS1_86a	2.87	0.0443	0.1183	0.0073	1919	75	1956	14
LHS1_87a	2.97	0.0399	0.1149	0.0072	2101	85	2135	15
LHS1_644a	2.85	0.0221	0.1182	0.0103	1941	37	1929	18
LHS1_645a	2.64	0.0258	0.1289	0.0117	2072	46	2083	20
LHS1_653a	3.01	0.0394	0.1137	0.0071	1849	63	1859	13
LHS1_678a	2.60	0.0388	0.1293	0.0073	2098	69	2088	13
LHS1_686a	2.86	0.0330	0.1183	0.0077	1931	55	1931	14
LHS1_695a	5.72	0.0251	0.0742	0.0140	1039	24	1047	28
LHS1_698a	2.60	0.0228	0.1293	0.0104	2096	41	2088	18
LHS1_716a	2.29	0.0426	0.1522	0.0104	2338	83	2371	18
LHS1_717a	3.20	0.0257	0.1152	0.0115	1752	39	1883	21
LHS1_722a	2.70	0.0389	0.1197	0.0078	2034	67	1952	14
LHS1_723a	2.93	0.0319	0.1140	0.0063	1894	52	1863	11
LHS1_725a	2.91	0.0527	0.1264	0.0112	1907	86	2048	20
LHS1_727a	2.65	0.0243	0.1270	0.0114	2063	43	2057	20
LHS1_742a	2.03	0.0376	0.1744	0.0057	2586	80	2600	9
LHS1_746a	2.65	0.0371	0.1299	0.0064	2061	65	2097	11
LHS1_751a	2.61	0.0248	0.1326	0.0115	2094	44	2133	20
LHS1_757a	2.64	0.0378	0.1277	0.0084	2071	67	2067	15

LHS1_769a	2.62	0.0241	0.1285	0.0111	2082	43	2078	19
LHS1_770a	2.91	0.0357	0.1148	0.0064	1906	59	1877	11
LHS1_771a	2.55	0.0349	0.1292	0.0063	2132	63	2087	11
LHS1_789a	2.64	0.0376	0.1282	0.0069	2068	66	2073	12
LHS1_796a	2.48	0.0231	0.1396	0.0110	2184	43	2222	19
LHS1_800a	2.59	0.0361	0.1294	0.0075	2108	65	2090	13
LHS1_822a	2.95	0.0374	0.1191	0.0061	1883	61	1942	11
LHS1_828a	2.57	0.0481	0.1393	0.0235	2121	86	2218	40
LHS1_832a	2.99	0.0385	0.1140	0.0071	1861	62	1863	13
LHS1_837a	5.68	0.0396	0.0740	0.0094	1045	38	1040	19
LHS1_840a	2.61	0.0359	0.1287	0.0066	2088	64	2080	12
LHS1_844a	2.83	0.0439	0.1183	0.0076	1954	73	1931	14
LHS1_846a	3.00	0.0368	0.1164	0.0085	1857	59	1902	15
LHS1_853a	2.86	0.0461	0.1124	0.0100	1934	76	1838	18
LHS1_862a	3.29	0.0324	0.1162	0.0136	1712	49	1898	24
LHS1_863a	2.59	0.0361	0.1345	0.0094	2106	64	2157	16
LHS1_866a	2.63	0.0464	0.1298	0.0113	2076	82	2095	20
LHS1_870a	2.58	0.0433	0.1305	0.0089	2109	77	2104	16
LHS1_873a	2.85	0.0469	0.1192	0.0106	1939	78	1944	19
LHS1_877a	3.00	0.0423	0.1128	0.0098	1852	68	1845	18
LHS1_881a	2.33	0.0387	0.1533	0.0170	2302	74	2383	29
LHS1_884a	5.71	0.0261	0.0743	0.0142	1040	25	1051	28
LHS1_891a	2.87	0.0372	0.1131	0.0113	1925	62	1849	20
LHS1_895a	2.85	0.0421	0.1131	0.0085	1940	70	1850	15
LHS1_899a	2.83	0.0632	0.1185	0.0142	1953	106	1934	25
LHS1_900a	2.65	0.0417	0.1294	0.0098	2061	73	2090	17
LHS1_902a	2.89	0.0606	0.1195	0.0135	1914	100	1949	24
LHS1_905a	2.59	0.0445	0.1280	0.0088	2104	79	2071	15
LHS1_908a	2.70	0.0401	0.1275	0.0113	2030	69	2064	20
LHS1_914a	2.92	0.0581	0.1256	0.0197	1898	95	2037	34
LHS1_921a	2.76	0.0239	0.1309	0.0154	1992	41	2110	27
LHS1_923a	2.94	0.0442	0.1188	0.0107	1887	72	1938	19
LHS1_929a	3.00	0.0465	0.1142	0.0114	1854	74	1868	20
LHS1_930a	2.84	0.0535	0.1227	0.0115	1947	89	1995	20
LHS1_933a	2.95	0.0462	0.1141	0.0106	1881	75	1866	19
LHS1_937a	3.04	0.0397	0.1125	0.0079	1835	63	1840	14
LHS1_940a	2.58	0.0450	0.1322	0.0113	2113	81	2128	20
LHS1_947a	2.62	0.0428	0.1428	0.0138	2084	76	2261	24
LHS1_950a	2.09	0.0516	0.1733	0.0099	2523	107	2589	16
LHS1_953a	2.30	0.0559	0.1653	0.0107	2325	108	2511	18

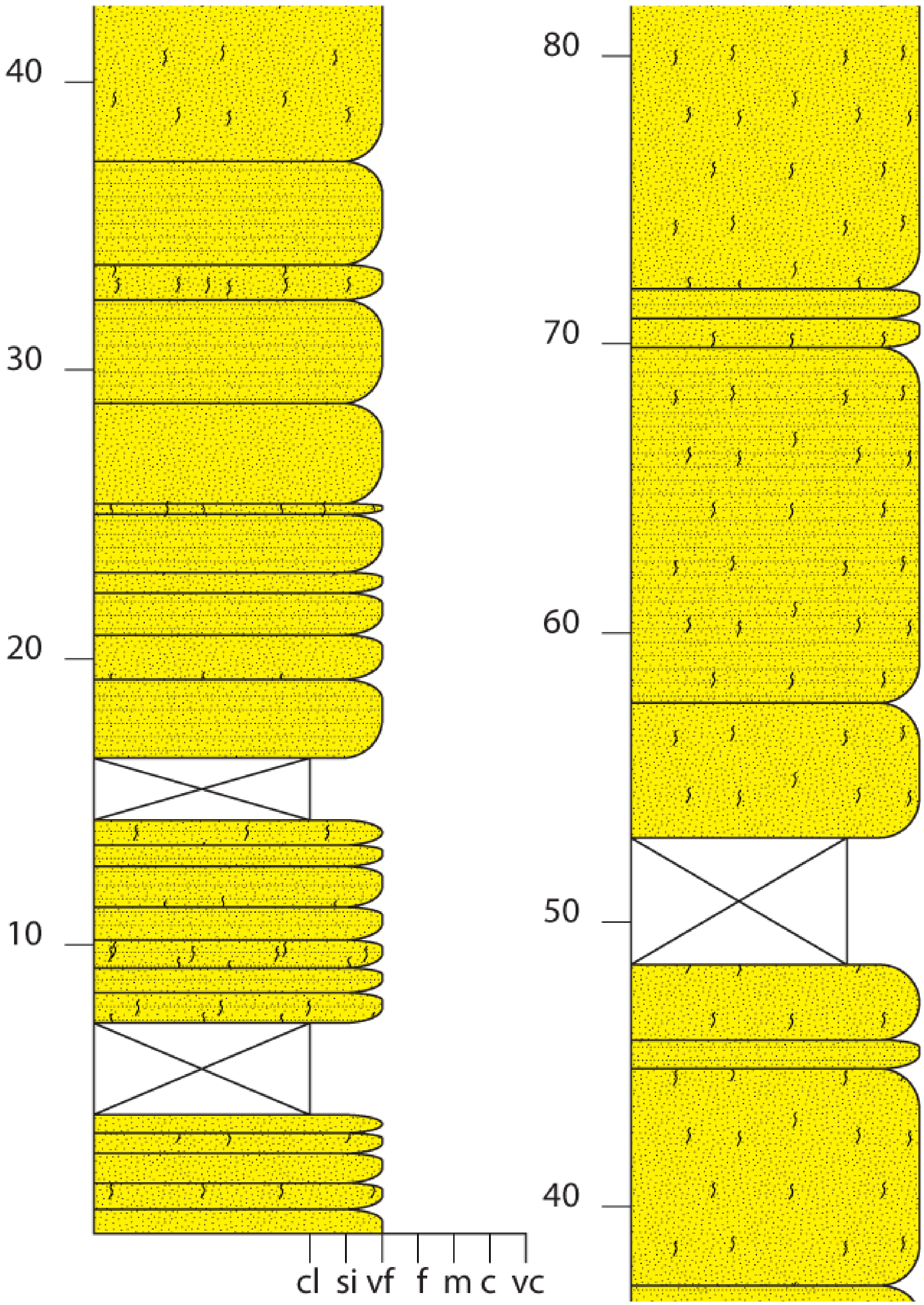
LHS1_955a	2.95	0.0485	0.1134	0.0121	1880	79	1855	22
LHS1_959a	3.07	0.0390	0.1140	0.0146	1816	61	1864	26
LHS1_961a	2.91	0.0359	0.1222	0.0087	1904	59	1988	15
LHS1_963a	3.06	0.0407	0.1128	0.0102	1824	64	1845	18
LHS1_966a	2.24	0.0436	0.1531	0.0075	2376	86	2381	13
LHS1_968a	2.94	0.0545	0.1173	0.0114	1889	89	1915	20
LHS1_973a	2.15	0.0386	0.1662	0.0067	2461	79	2520	11
LHS1_976a	2.53	0.0459	0.1260	0.0169	2150	83	2042	30
LHS1_978a	2.58	0.0495	0.1303	0.0108	2115	89	2101	19
LHS1_984a	3.12	0.0443	0.1160	0.0112	1791	69	1895	20
LHS1_986a	2.89	0.0446	0.1148	0.0120	1913	73	1877	21
LHS1_988a	2.60	0.0489	0.1296	0.0095	2101	87	2093	17
LHS1_991a	2.86	0.0585	0.1248	0.0108	1931	97	2026	19
LHS1_1001a	2.68	0.0509	0.1279	0.0107	2045	89	2069	19
			>10% Discordant					
LHS1_20a	#VALUE!	######	0.4085	0.0407	#VALUE!	###	3941	60
LHS1_71a	2.94	0.0474	0.1127	0.0095	1086	45	1732	45
LHS1_658a	3.09	0.0522	0.1517	0.0224	1806	82	2365	38
LHS1_671a	2.82	0.0376	0.1666	0.0114	1955	63	2524	19
LHS1_676a	23.20	0.0268	0.2679	0.0104	272	7	3294	16
LHS1_691a	3.40	0.0407	0.1237	0.0105	1660	59	2011	19
LHS1_772a	3.21	0.0387	0.1198	0.0252	1747	59	1953	44
LHS1_777a	#VALUE!	######	0.2425	0.0411	#VALUE!	###	3136	64
LHS1_787a	3.69	0.0543	0.1262	0.0125	1547	74	2045	22
LHS1_805a	3.66	0.0501	0.1407	0.0200	1559	69	2236	34
LHS1_806a	3.24	0.0525	0.1322	0.0151	1735	79	2127	26
LHS1_812a	6.26	0.0458	0.0826	0.0168	956	41	1260	32
LHS1_813a	#VALUE!	######	0.2846	0.0307	#VALUE!	###	3389	47
LHS1_830a	3.17	0.0396	0.1249	0.0109	1765	61	2027	19
LHS1_847a	3.11	0.0541	0.1769	0.0372	1796	84	2624	61
LHS1_909a	3.17	0.0469	0.1219	0.0077	1768	72	1984	14
LHS1_949a	2.31	0.0404	0.1837	0.0195	2317	78	2687	32
LHS1_965a	3.76	0.0570	0.1417	0.0235	1521	77	2248	40
LHS1_999a	#VALUE!	######	0.4049	0.0261	#VALUE!	###	3927	39

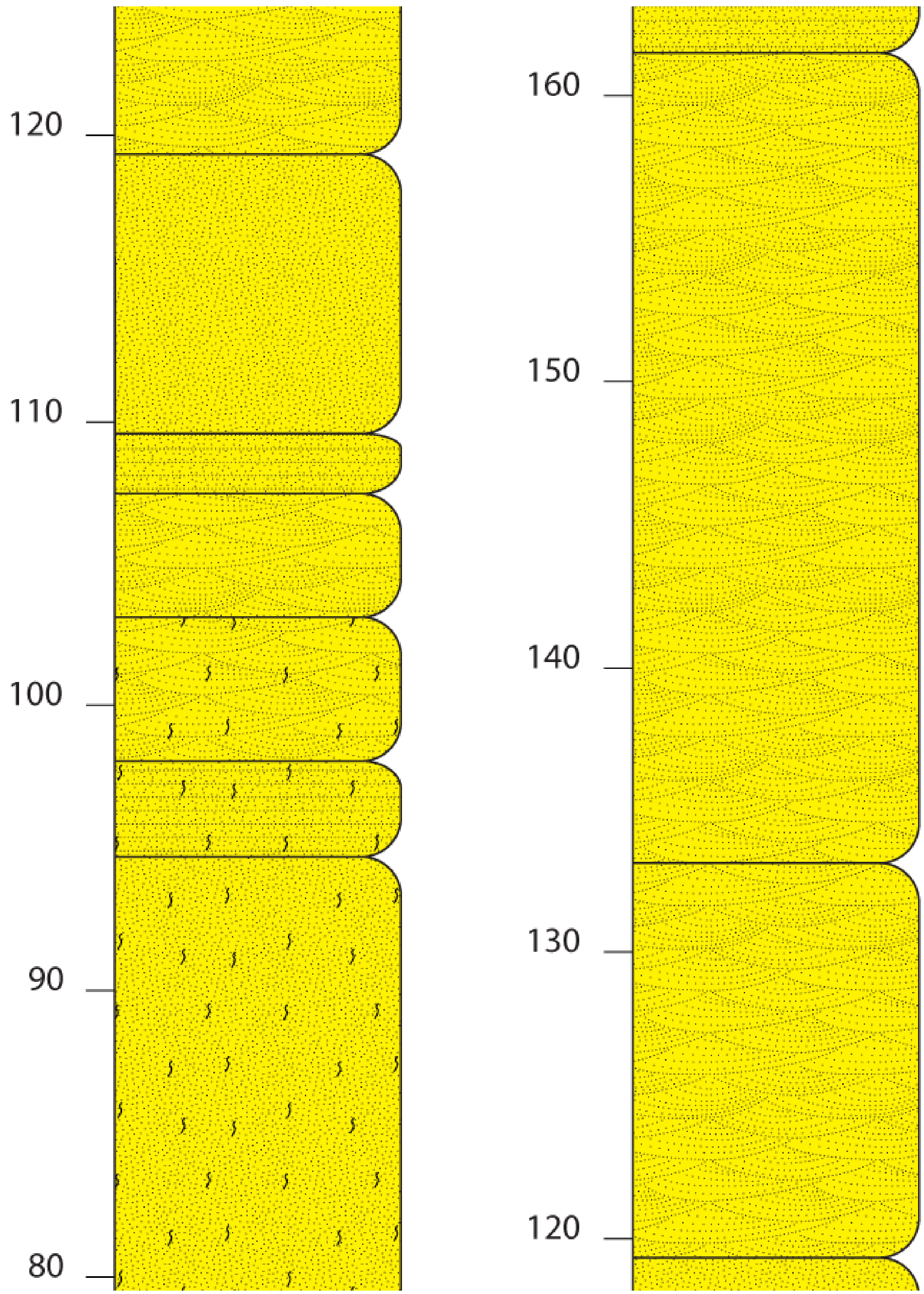
WETHERILL PLOTS





STRATIGRAPHIC MEASURED SECTION

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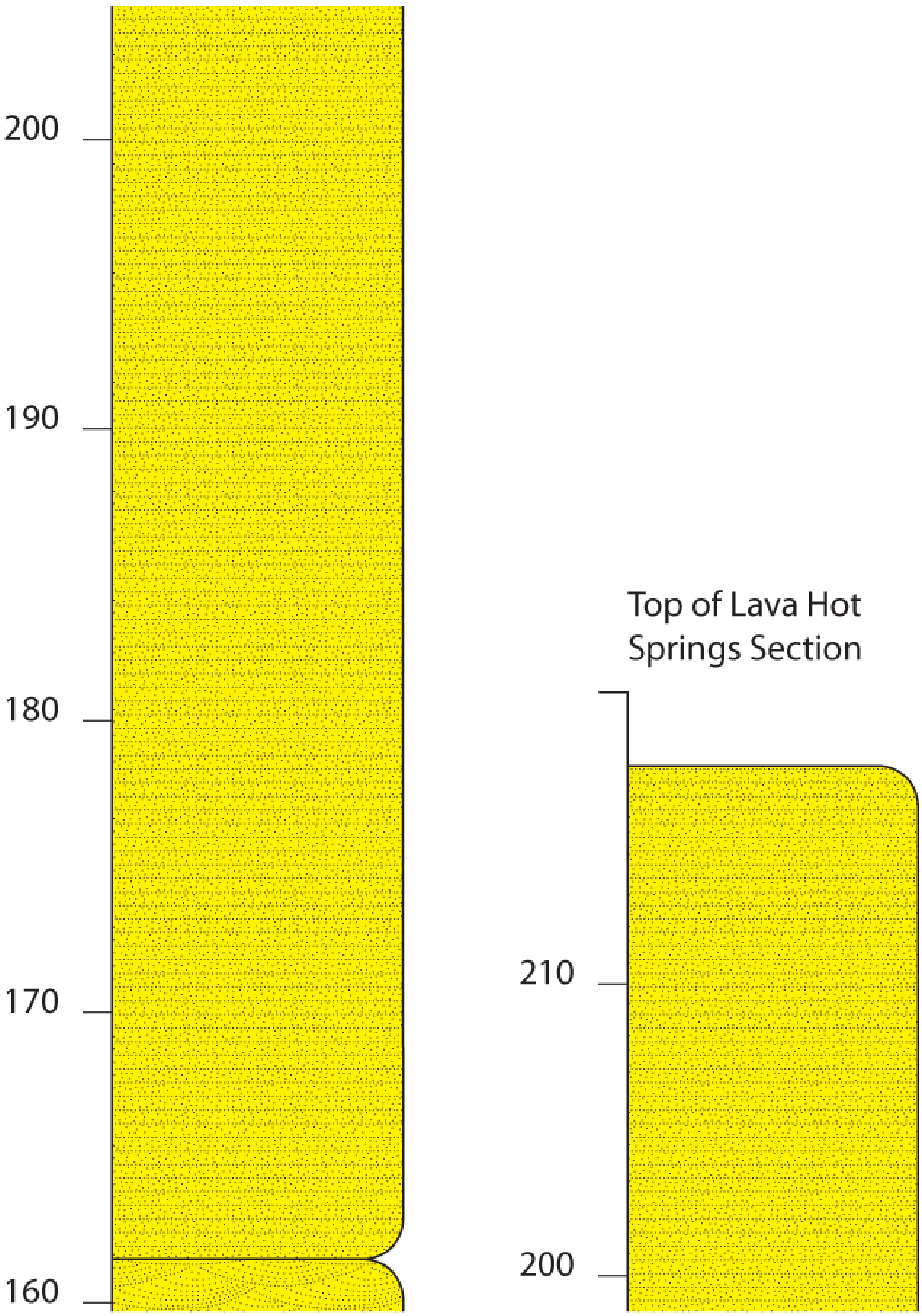

200
190
180
170
160
Top of Lava Hot
Springs Section
210
200

APPENDIX E

WOODRUFF SECTION

DATA TABLE

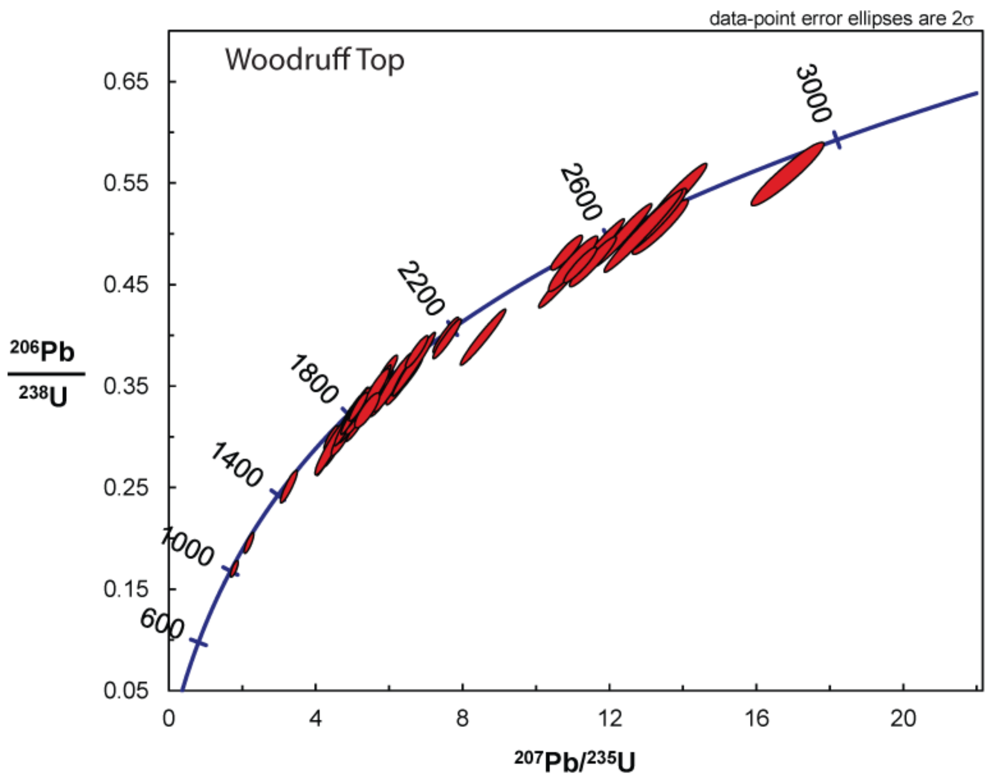
C-9 Woodruff Top

Sample	$^{238}U/^{206}PB$	1σ (%)	$^{207}Pb/^{206}PB$	1σ (%)	$^{238}U/^{206}PB$ Age (Ma)	1σ	$^{207}Pb/^{206}PB$ Age (Ma)	1σ
			Woodruff (Top) <10% Discordant					
Wood2_156a	3.96	0.0260	0.0934	0.0125	1450	34	1497	23
Wood2_157a	3.02	0.0253	0.1146	0.0081	1844	41	1874	15
Wood2_158a	3.15	0.0283	0.1130	0.0100	1777	44	1848	18
Wood2_159a	3.11	0.0249	0.1126	0.0079	1795	39	1842	14
Wood2_161a	3.05	0.0221	0.1174	0.0107	1827	35	1918	19
Wood2_165a	3.30	0.0534	0.1107	0.0102	1704	79	1811	18
Wood2_171a	1.79	0.0227	0.2180	0.0080	2867	52	2966	13
Wood2_177a	2.00	0.0257	0.1791	0.0063	2612	55	2645	10
Wood2_184a	3.14	0.0209	0.1162	0.0086	1780	32	1899	15
Wood2_185a	1.97	0.0218	0.1908	0.0080	2647	47	2749	13
Wood2_186a	3.17	0.0189	0.1164	0.0081	1767	29	1901	14
Wood2_190a	2.06	0.0253	0.1739	0.0059	2551	53	2595	10
Wood2_191a	2.80	0.0264	0.1268	0.0071	1971	45	2054	12
Wood2_194a	1.99	0.0199	0.1867	0.0058	2619	43	2713	9
Wood2_199a	3.17	0.0184	0.1122	0.0077	1766	28	1836	14
Wood2_202a	2.82	0.0202	0.1241	0.0093	1958	34	2017	16
Wood2_203a	1.85	0.0232	0.1857	0.0067	2783	52	2705	11
Wood2_207a	3.13	0.0247	0.1127	0.0072	1787	38	1843	13
Wood2_214a	2.78	0.0174	0.1300	0.0088	1981	30	2098	15
Wood2_216a	1.95	0.0258	0.1867	0.0088	2670	56	2713	14
Wood2_217a	2.19	0.0261	0.1707	0.0067	2427	53	2564	11
Wood2_219a	3.14	0.0225	0.1111	0.0072	1780	35	1818	13
Wood2_222a	2.91	0.0226	0.1169	0.0104	1904	37	1909	19
Wood2_227a	3.09	0.0189	0.1131	0.0114	1809	30	1849	21
Wood2_234a	3.08	0.0249	0.1145	0.0093	1811	39	1872	17
Wood2_238a	3.10	0.0190	0.1146	0.0085	1800	30	1873	15
Wood2_247a	2.72	0.0255	0.1298	0.0086	2015	44	2095	15
Wood2_249a	2.73	0.0174	0.1307	0.0075	2012	30	2108	13
Wood2_255a	2.66	0.0197	0.1291	0.0081	2059	35	2086	14
Wood2_256a	2.50	0.0285	0.1551	0.0071	2166	52	2403	12
Wood2_258a	3.04	0.0199	0.1127	0.0106	1833	32	1844	19
Wood2_259a	5.07	0.0213	0.0796	0.0147	1160	23	1186	29
Wood2_262a	3.20	0.0221	0.1118	0.0109	1752	34	1829	20
Wood2_264a	2.87	0.0265	0.1184	0.0112	1929	44	1933	20

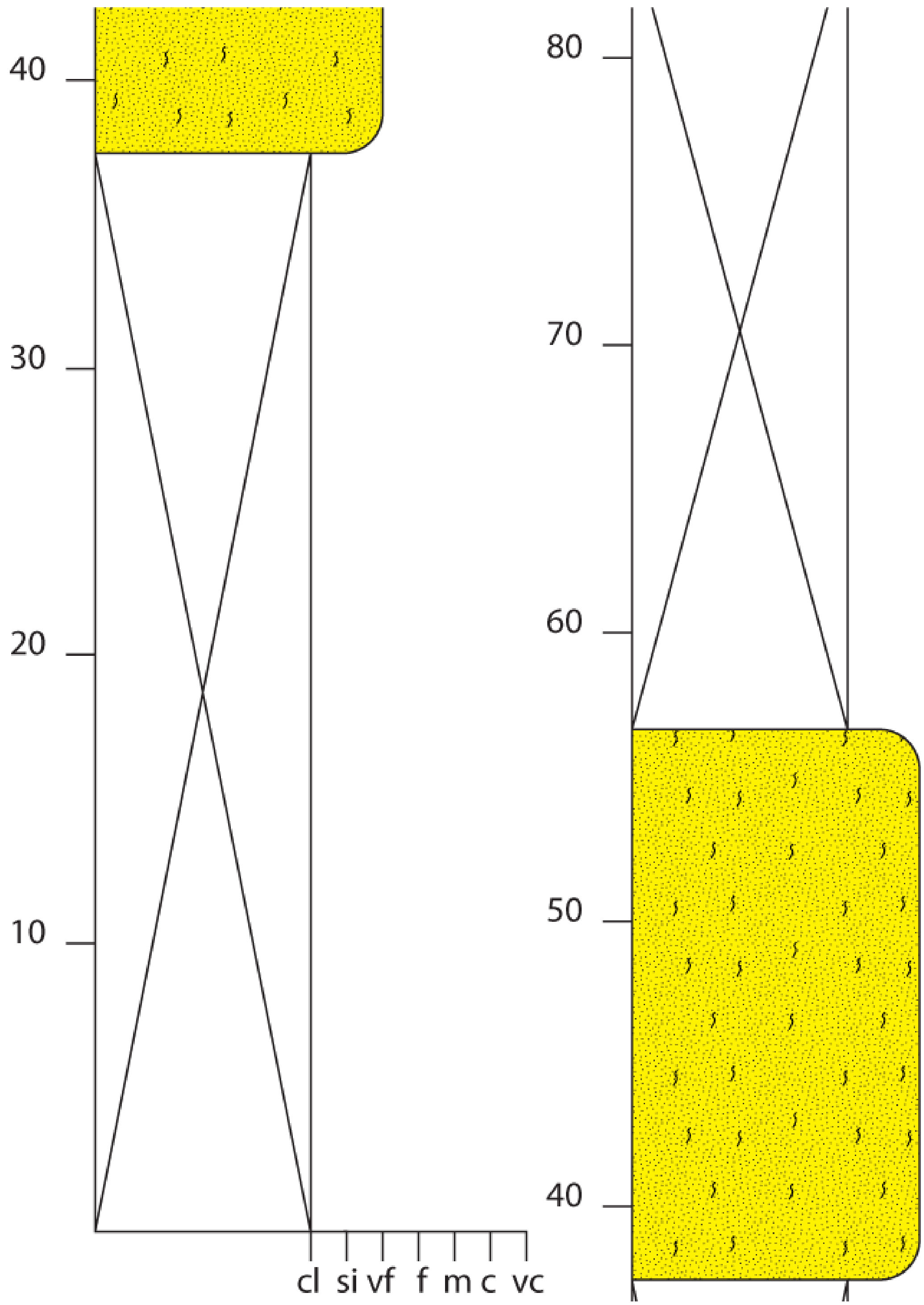
Wood2_270a	2.74	0.0186	0.1281	0.0070	2008	32	2071	12
Wood2_271a	3.32	0.0160	0.1059	0.0080	1697	24	1730	15
Wood2_273a	3.00	0.0337	0.1164	0.0116	1855	54	1902	21
Wood2_275a	2.80	0.0247	0.1297	0.0072	1967	42	2094	13
Wood2_276a	3.20	0.0237	0.1115	0.0120	1752	36	1825	22
Wood2_280a	1.98	0.0330	0.1857	0.0069	2631	71	2704	11
Wood2_281a	2.12	0.0237	0.1690	0.0089	2491	49	2548	15
Wood2_286a	2.96	0.0170	0.1151	0.0066	1875	28	1882	12
Wood2_287a	3.13	0.0242	0.1135	0.0094	1789	38	1856	17
Wood2_288a	2.95	0.0213	0.1237	0.0102	1882	35	2011	18
Wood2_289a	3.34	0.0377	0.1127	0.0101	1690	56	1843	18
Wood2_290a	2.99	0.0220	0.1161	0.0065	1859	35	1898	12
Wood2_291a	3.13	0.0231	0.1136	0.0089	1788	36	1857	16
Wood2_293a	2.76	0.0207	0.1176	0.0085	1996	35	1920	15
Wood2_294a	2.11	0.0213	0.1765	0.0071	2499	44	2621	12
Wood2_298a	3.02	0.0225	0.1137	0.0075	1842	36	1859	13
Wood2_303a	3.08	0.0326	0.1121	0.0082	1812	51	1834	15
Wood2_304a	3.16	0.0336	0.1114	0.0100	1772	52	1822	18
Wood2_306a	2.71	0.0198	0.1290	0.0113	2022	34	2084	20
Wood2_308a	3.04	0.0341	0.1169	0.0109	1834	54	1909	20
Wood2_310a	2.49	0.0178	0.1358	0.0072	2177	33	2174	12
Wood2_311a	2.99	0.0237	0.1168	0.0113	1860	38	1907	20
Wood2_312a	2.76	0.0336	0.1292	0.0096	1996	57	2087	17
Wood2_314a	3.17	0.0243	0.1171	0.0122	1767	37	1913	22
Wood2_315a	3.10	0.0166	0.1128	0.0116	1801	26	1845	21
Wood2_316a	2.82	0.0338	0.1248	0.0099	1958	57	2025	17
Wood2_318a	2.94	0.0128	0.1182	0.0064	1889	21	1930	11
Wood2_319a	3.44	0.0369	0.1097	0.0133	1643	53	1794	24
Wood2_321a	3.34	0.0225	0.1140	0.0110	1688	33	1864	20
Wood2_322a	2.72	0.0135	0.1282	0.0071	2016	23	2074	12
Wood2_323a	2.97	0.0164	0.1186	0.0093	1872	27	1936	16
Wood2_324a	2.91	0.0344	0.1174	0.0084	1902	56	1917	15
Wood2_325a	3.08	0.0169	0.1116	0.0115	1812	27	1825	21
Wood2_326a	2.91	0.0114	0.1173	0.0058	1905	19	1915	10
Wood2_327a	2.74	0.0184	0.1298	0.0088	2005	32	2096	15
Wood2_329a	3.07	0.0195	0.1124	0.0084	1817	31	1839	15
Wood2_331a	3.01	0.0216	0.1126	0.0095	1848	35	1842	17
Wood2_332a	2.77	0.0180	0.1296	0.0086	1990	31	2092	15
Wood2_333a	2.70	0.0320	0.1287	0.0077	2034	56	2081	13
Wood2_335a	2.07	0.0147	0.1626	0.0069	2538	31	2483	12

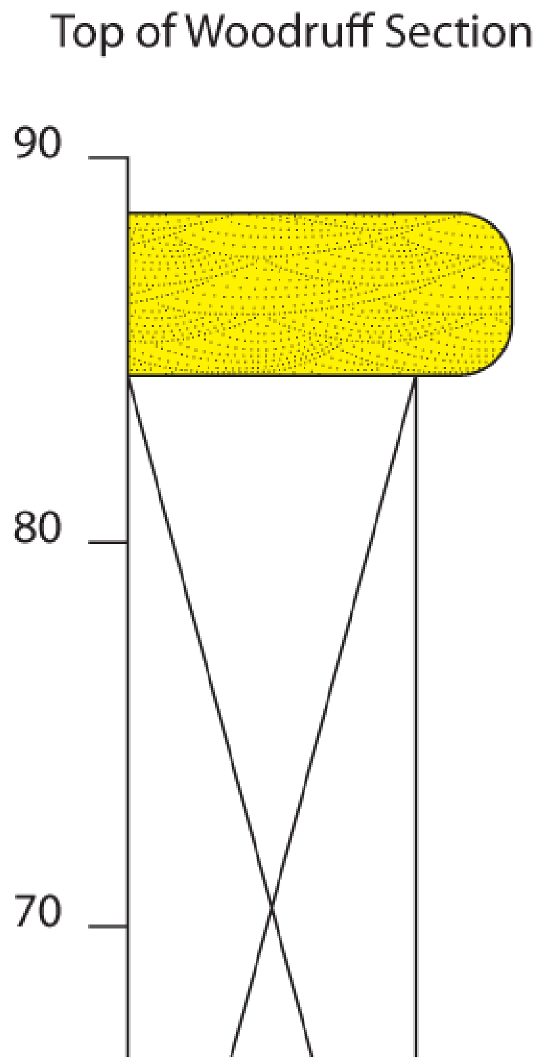
Wood2_336a	2.68	0.0343	0.1296	0.0082	2042	60	2093	14
Wood2_338a	2.82	0.0113	0.1177	0.0058	1954	19	1922	10
Wood2_345a	3.17	0.0192	0.1113	0.0081	1770	30	1821	15
Wood2_346a	3.20	0.0231	0.1132	0.0116	1755	35	1851	21
Wood2_348a	3.11	0.0200	0.1151	0.0133	1799	31	1882	24
Wood2_349a	2.86	0.0220	0.1169	0.0110	1934	37	1909	20
Wood2_351a	3.14	0.0332	0.1118	0.0100	1783	52	1829	18
Wood2_353a	3.13	0.0207	0.1154	0.0104	1788	32	1886	19
Wood2_355a	3.12	0.0160	0.1124	0.0088	1794	25	1839	16
Wood2_356a	3.15	0.0176	0.1120	0.0069	1776	27	1833	12
Wood2_357a	3.06	0.0124	0.1123	0.0072	1824	20	1837	13
Wood2_358a	2.60	0.0170	0.1270	0.0075	2099	30	2056	13
Wood2_360a	2.13	0.0154	0.1725	0.0064	2486	32	2582	11
Wood2_361a	5.84	0.0189	0.0749	0.0156	1020	18	1066	31
Wood2_362a	3.02	0.0175	0.1128	0.0086	1842	28	1846	15
Wood2_367a	2.51	0.0200	0.1380	0.0069	2158	37	2202	12
Wood2_800a	3.06	0.0216	0.1194	0.0140	1825	34	1947	25
			>10% Discordant					
Wood2_162a	2.84	0.0259	0.1724	0.0251	1945	43	2581	41
Wood2_174a	2.67	0.0311	0.1528	0.0285	2052	54	2378	48
Wood2_204a	3.10	0.0294	0.1273	0.0186	1802	46	2061	32
Wood2_218a	5.97	0.0251	0.1069	0.0136	999	23	1747	25
Wood2_268a	2.96	0.0223	0.1312	0.0167	1874	36	2114	29
Wood2_272a	3.29	0.0225	0.1180	0.0119	1709	34	1927	21
Wood2_283a	3.38	0.0279	0.1811	0.0074	1672	41	2663	12
Wood2_285a	3.17	0.0333	0.1231	0.0100	1765	51	2002	18
Wood2_339a	3.31	0.0323	0.1183	0.0075	1704	48	1931	13

WETHERILL PLOT



STRATIGRAPHIC MEASURED SECTION

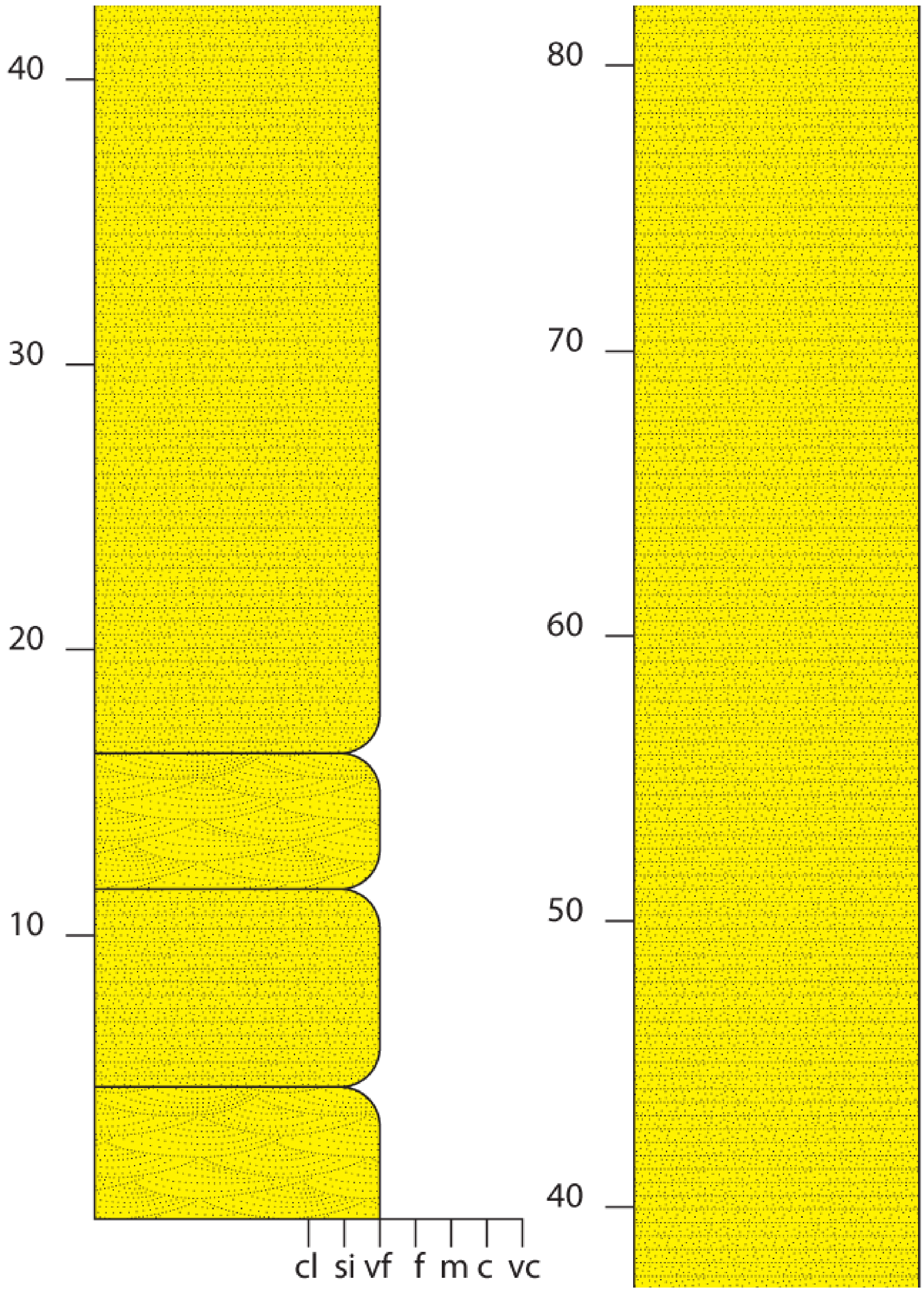


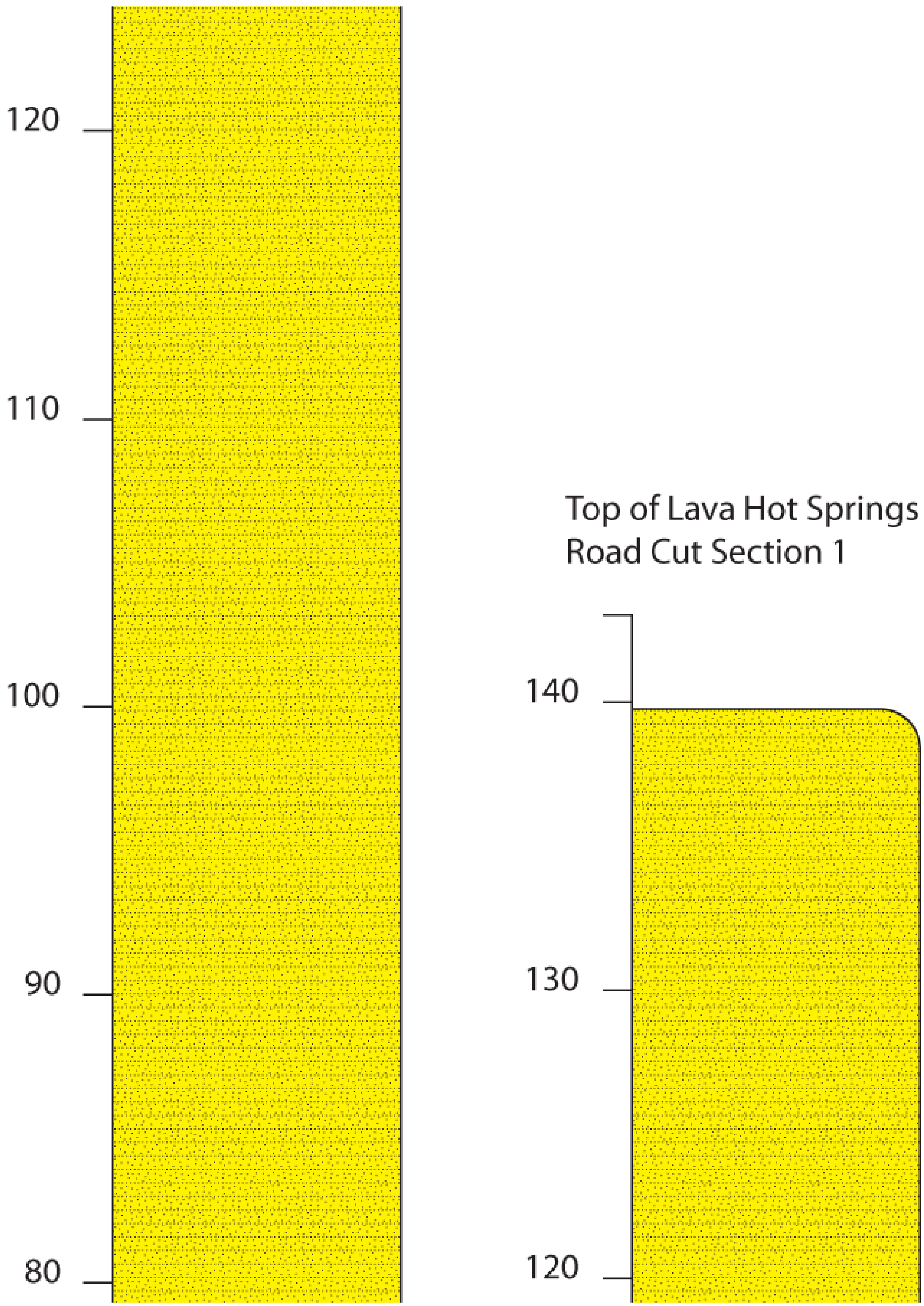

Top of Woodruff Section
90
80
70

APPENDIX F

LAVA HOT SPRINGS ROAD CUT SECTION 1

STRATIGRAPHIC MEASURED SECTION

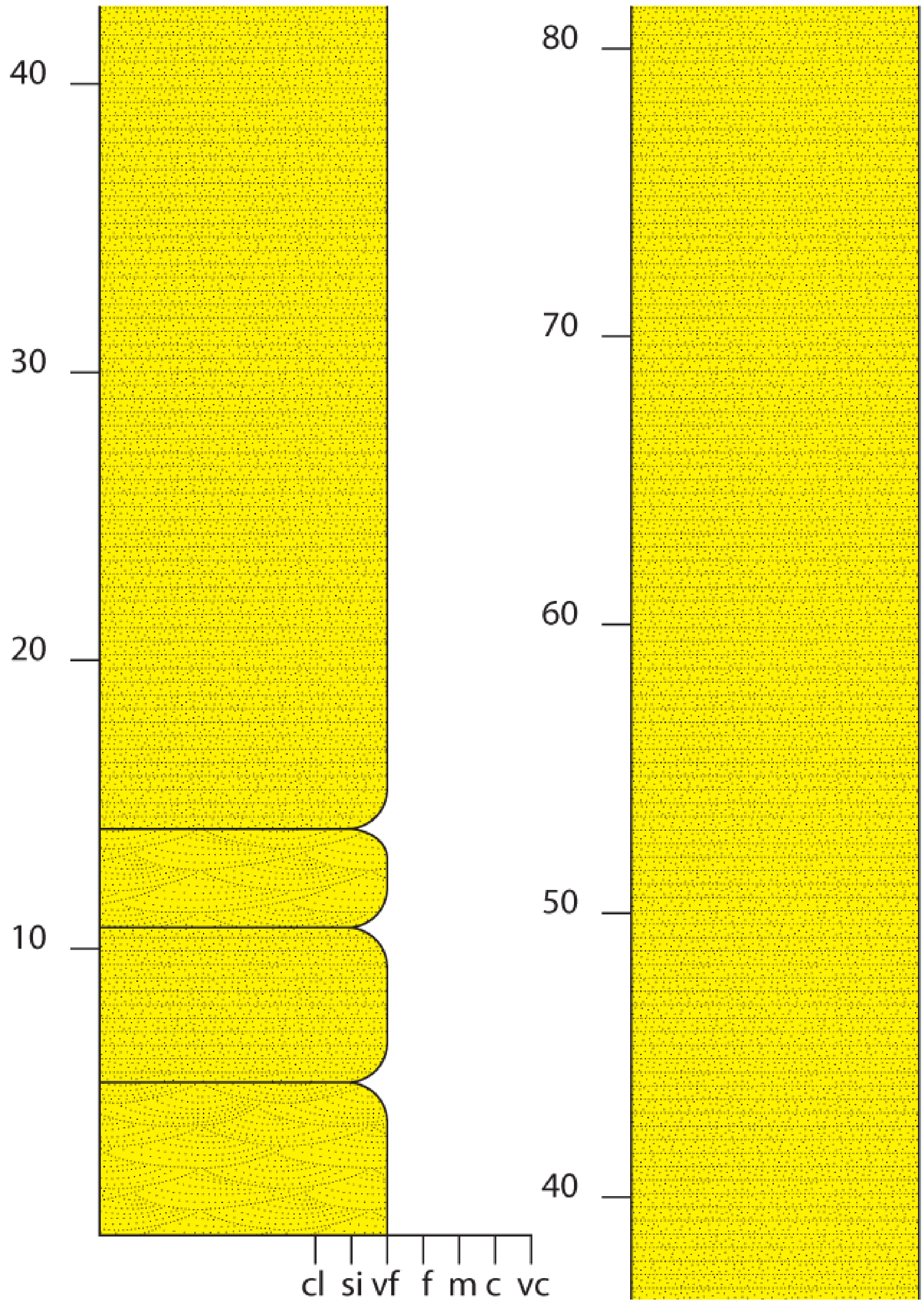



120
110
100
90
80
Top of Lava Hot Springs
Road Cut Section 1
140
130
120

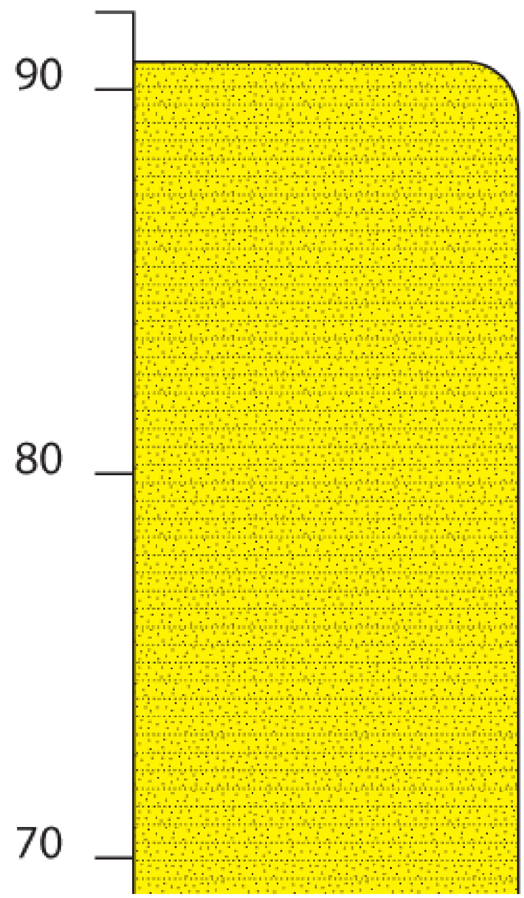
APPENDIX G

LAVA HOT SPRINGS ROAD CUT SECTION 2

STRATIGRAPHIC MEASURED SECTION



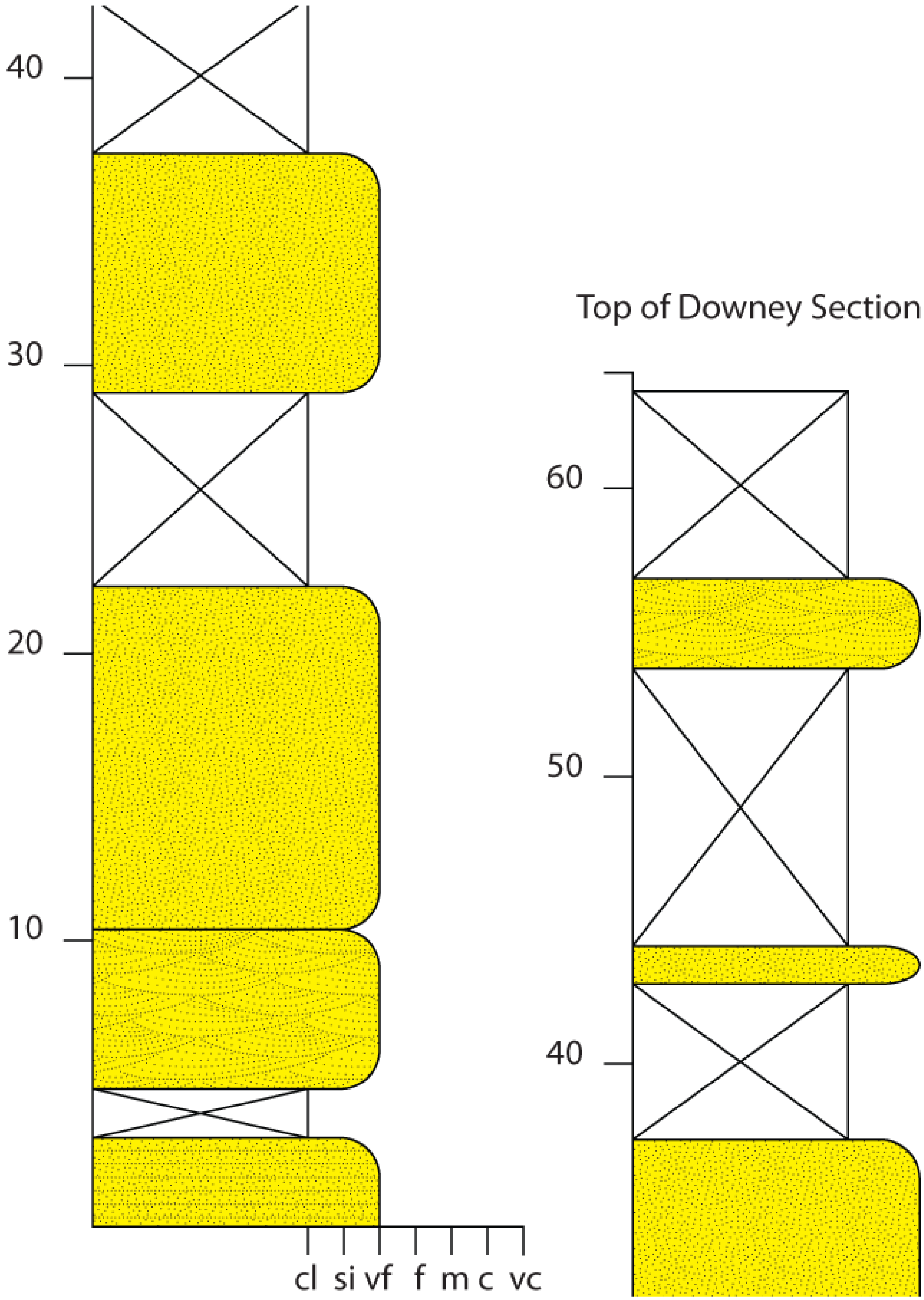
Top of Lava Hot Springs
Road Cut Section 2



APPENDIX H

DOWNEY SECTION

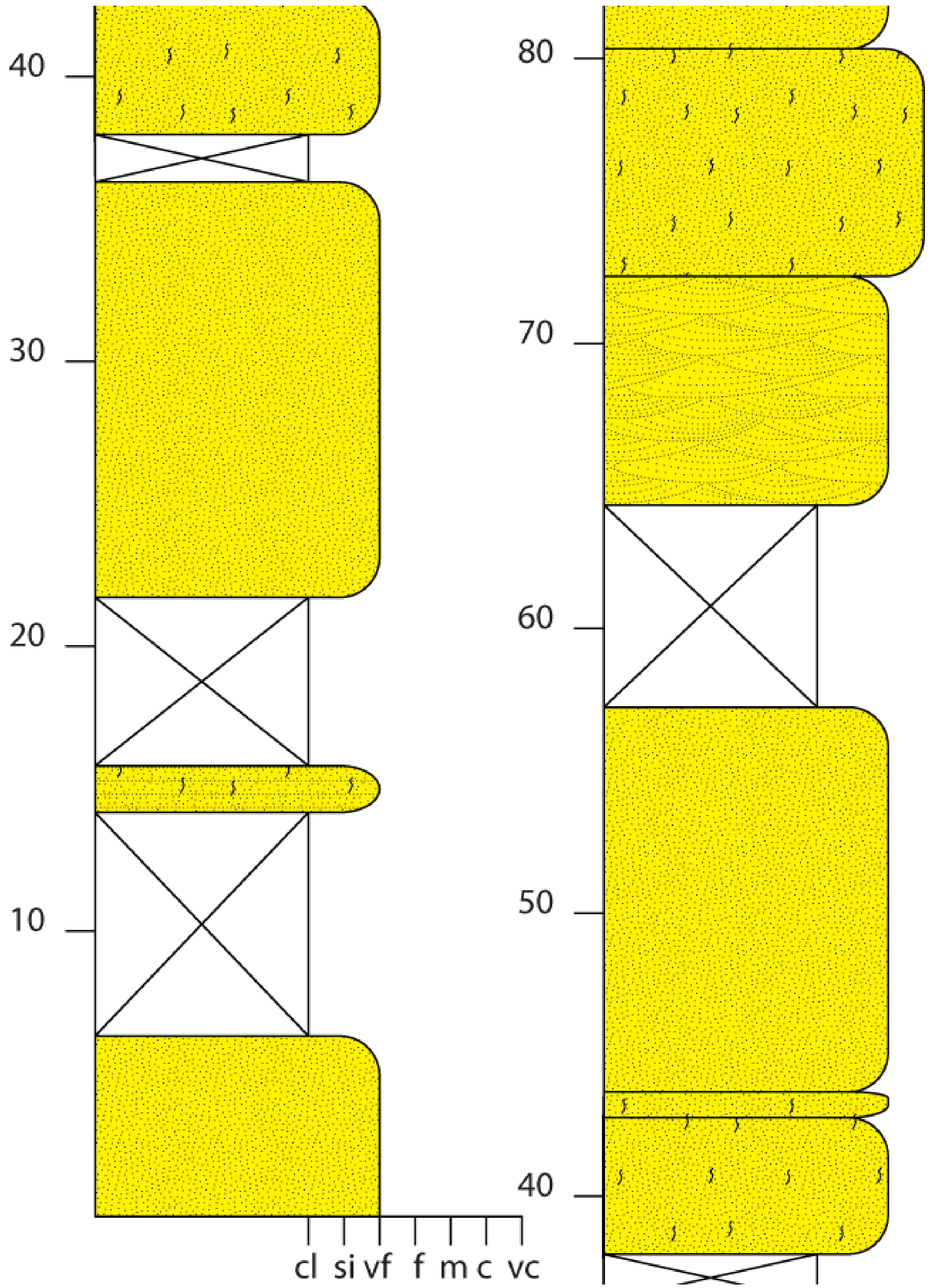
STRATIGRAPHIC MEASURED SECTION

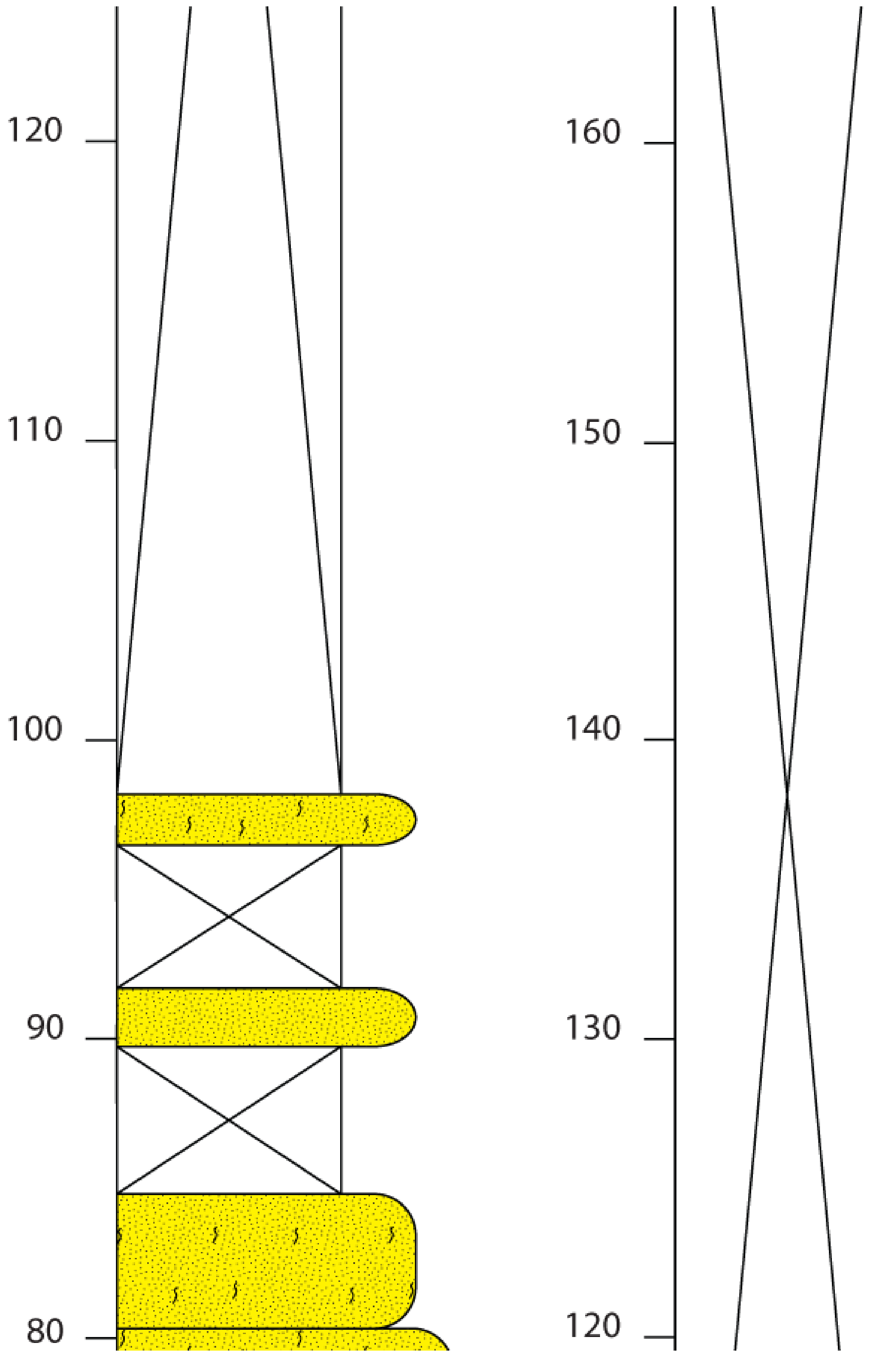


APPENDIX I

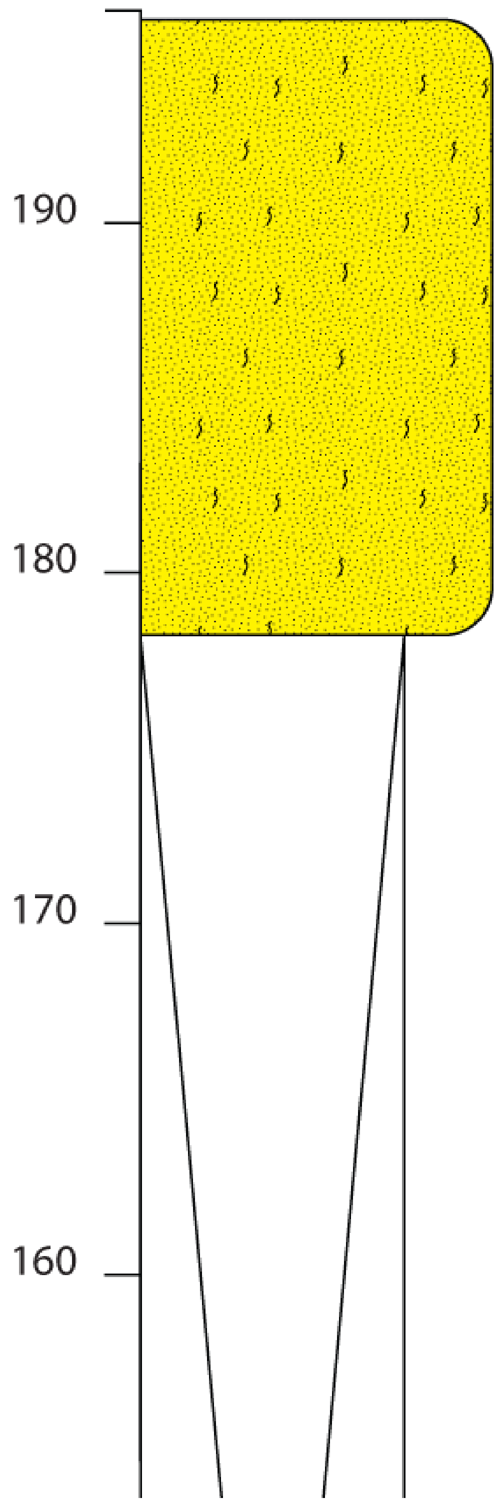
ELKHORN PEAK SECTION

STRATIGRAPHIC MEASURED SECTION




120
110
100
90
80
160
150
140
130
120

Top of Elkhorn Peak Section



VITA

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